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Editor : Anil Ahlawat
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Dropleton - A New Particle?

According to the authors who have discovered microscopic particle clusters in solids, which behave like a liquid, have the properties of a quasi particle.

This particle has a very short life span. Stimulated by light, the smaller particles briefly condense into a 'droplet' with the characteristics of liquid water. This can have ripples. The life time of this droplet is only about 25 pica seconds (trillionth of a second). The interaction of light was by lasers - gallium arsenide. This strangely behaves like a liquid. It is thought that five electrons are forming the new particle with five holes. The very short life-time of the particle, the changing positions of these particles (or electron-hole combinations) give it an appearance of a liquid drop.

These experiments need a high degree of experimental skill.

In order to evaluate and appreciate the new aspects in this experiment, I am quoting what is given in the Penguin Dictionary of Physics. "Exciton : An electron in combination with a hole in a crystalline solid. The electron has gained sufficient energy to be in an excited state and is bound by electrostatic attraction to the positive hole. The exciton may migrate through the solid by electrostatic attraction to the positive hole. The excitation may migrate through the solid and eventually the hole and electron recombine with emission of a photon."

Any new discovery should excite our students. Our advice to our research students is this: appreciate what others have done and learn what other scientists have performed earlier. Making that as a starting point, one has to go further devising ones own methods and extensions.

Anil Ahlawat
Editor

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Physics Musing was started in August 2013 issue of Physics For You with the suggestion of Shri Mahabir Singh. The aim of Physics Musing is to augment the chances of bright students preparing for JEE (Main and Advanced) / AIIMS / Other PMTs with additional study material.

In every issue of Physics For You, 10 challenging problems are proposed in various topics of JEE (Main and Advanced) / various PMTs. The detailed solutions of these problems will be published in next issue of Physics For You.

The readers who have solved five or more problems may send their solutions. The names of those who send atleast five correct solutions will be published in the next issue.

We hope that our readers will enrich their problem solving skills through "Physics Musing" and stand in better stead while facing the competitive exams.

By : Akhil Tewari

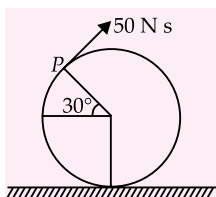
PROBLEM Set 9

MORE THAN ONE OPTION CORRECT

- A diminished image of an object is to be obtained on a screen 1 m away from it. This can be achieved by approximately placing
 - a convex mirror of suitable focal length
 - a concave mirror of suitable focal length
 - a convex lens of focal length less than 0.25 m
 - a concave lens of suitable focal length.
- Two lenses, one concave and the other convex of same power are placed such that their principal axis coincide. If the separation between the lenses is x , then
 - real image is formed for $x = 0$ only
 - real image is formed for all values of x
 - system will behave like a glass plate for $x = 0$
 - virtual image is formed for all values of x other than zero.

SINGLE OPTION CORRECT

- A solid ball of radius 0.2 m and mass 1 kg lying at rest on a smooth horizontal surface is given an instantaneous impulse of 50 N s at point P as shown. The number of rotations made by the ball about its diameter before hitting the ground is

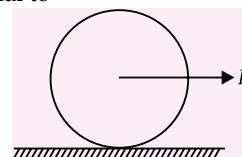


- $\frac{625\sqrt{3}}{2\pi}$
- $\frac{2500\sqrt{3}}{2\pi}$

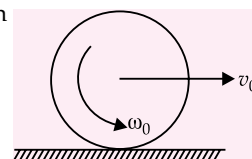
- $\frac{3125\sqrt{3}}{2\pi}$
- $\frac{1250\sqrt{3}}{2\pi}$

- The coefficient of friction between ground and sphere is μ . The maximum value of F , so that sphere will not slip, is equal to

- $\frac{7}{5}\mu mg$
- $\frac{4}{7}\mu mg$
- $\frac{5}{7}\mu mg$
- $\frac{7}{2}\mu mg$



- A disc of radius R is spun to an angular speed ω_0 about its axis and then imparted a horizontal velocity of magnitude $\frac{\omega_0 R}{4}$ (at $t = 0$) with its plane remaining vertical.



- The coefficient of friction between the disc and the plane is μ . The sense of rotation and direction of its linear speed are shown in the figure. Choose the correct statement.

- Disc will start rolling without slipping in the direction of v_0
 - Slipping will never be ceased
 - Disc will return to initial point
 - None of these
- Two long parallel wires carry equal current I flowing in the same direction are at a distance



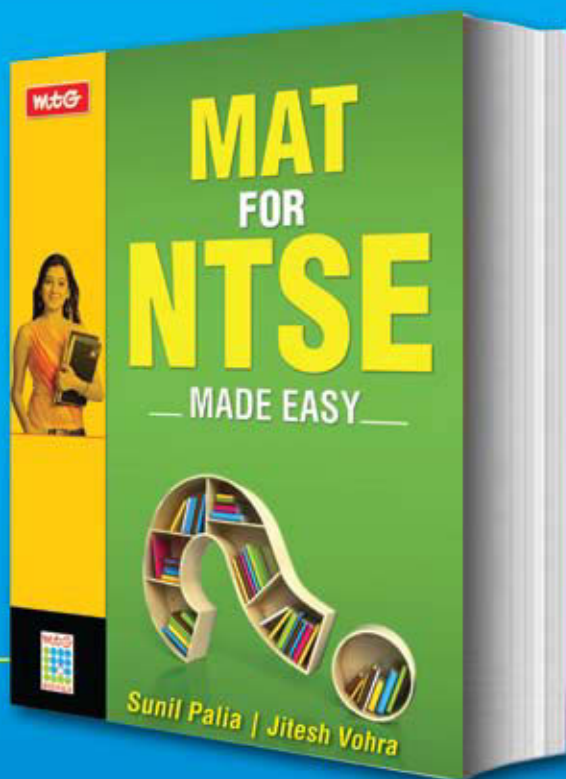
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DO YOU KNOW?

- The average ocean floor is about 3,600 m deep.
- Sunlight can penetrate clean ocean water to a depth of 73 m.
- Due to gravitational effects, you weigh slightly less when the Moon is directly overhead.
- When glass breaks, the cracks move at speeds of more than $4,500 \text{ km h}^{-1}$.
- On a clear day, beam of sunlight can be reflected off a mirror and seen up to 40 km away.
- There is enough fuel in a full tank of a jumbo jet to drive an average car around the world four times.
- On average, our bodies constantly resist an atmospheric pressure of about 1 kg per square cm.
- The deepest location on Earth is Mariana Trench, about 11 km deep in the North Pacific ocean.
- If Mount Everest were placed at the bottom of the deepest part of the ocean, its peak would still be a mile under water.
- Many physicists believe wormholes (a shortcut through space and time) exist all around us but they are smaller than atoms.
- If you yelled for 8 years, 7 months and 6 days, you would have produced just enough sound energy to heat up one cup of coffee.
- Minus 40 degrees Celsius is exactly the same temperature as minus 40 degrees Fahrenheit.
- Mexico City is sinking at a rate of 46 cm per year as a result of draining water.
- The oldest and largest clearly visible meteorite crater site in the world is The Vredefort Dome in Free State, South Africa. It is 380 km across.
- The greatest tide change on earth occurs in the Bay of Fundy. The difference between low tide and high tide can be as great as 16.6 m.
- The average ice berg weighs 20,000,000 tons.
- Lightning strikes about 6,000 times per minute on our planet.
- The Moon is moving away from the Earth 3.8 cm every year.
- The entire surface area of Pluto is smaller than Russia.
- 95% of all matter in the universe is invisible, and is called the Dark Matter.
- Proxima Centauri is the nearest star to us after the Sun.
- A supermassive blackhole is believed to be present in the centre of nearly every galaxy, including our own Milky Way.
- All 27 of Uranus moons are named after William Shakespeare and Alexander Pope characters.

$2d$ apart. The magnetic field B at a point lying on the perpendicular line joining the wires and at a distance x from the midpoint is

- (a) $\frac{\mu_0 I d}{\pi(d^2 + x^2)}$ (b) $\frac{\mu_0 I x}{\pi(d^2 - x^2)}$
 (c) $\frac{\mu_0 I x}{(d^2 + x^2)}$ (d) $\frac{\mu_0 I d}{(d^2 + x^2)}$

7. A bullet of mass 0.01 kg, travelling at a speed of 500 m s^{-1} , strikes a block of mass 2 kg, which is suspended by a string of length 5 m, and emerges out. The block rises by a vertical distance of 0.1 m. The speed of the bullet after it emerges from the block is

- (a) 55 m s^{-1} (b) 110 m s^{-1}
 (c) 220 m s^{-1} (d) 440 m s^{-1}

8. An electron of mass m moving with a velocity v collides head on with an atom of mass M . As a result of the collision a certain fixed amount of energy ΔE is stored internally in the atom. The minimum initial velocity possessed by the electron is

- (a) $\sqrt{\frac{2(M-m)\Delta E}{Mm}}$ (b) $\sqrt{\frac{2M\Delta E}{(M+m)m}}$
 (c) $\sqrt{\frac{2(M+m)\Delta E}{Mm}}$ (d) none of these

9. A straight rod of length L extends from $x = a$ to $x = L + a$. The gravitational force exerted on a point mass m at $x = 0$ if the mass per unit length of the rod is $A + Bx^2$, is

- (a) $Gm \left[\frac{A}{a+L} - \frac{A}{a} + BL \right]$
 (b) $Gm \left[\frac{A}{a} - \frac{A}{a+L} + BL \right]$
 (c) $Gm \left[\frac{A}{a+L} - \frac{A}{a} - BL \right]$
 (d) $Gm \left[\frac{A}{a} - \frac{A}{a+L} - BL \right]$

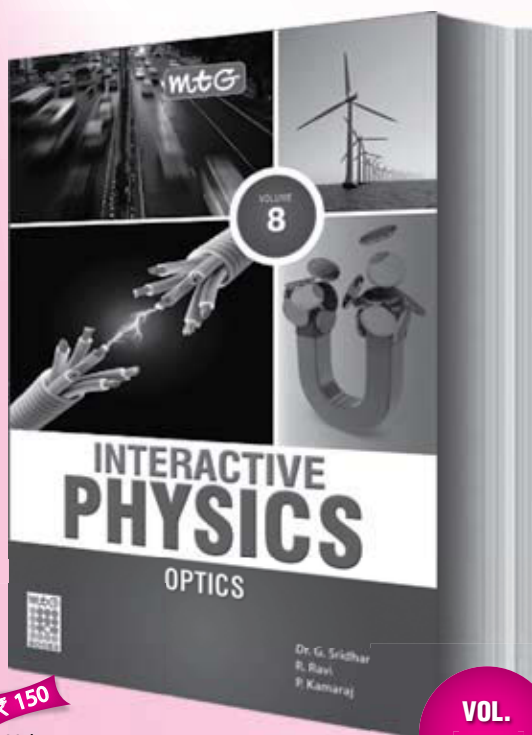
10. An artificial satellite moving in a circular orbit around the earth has a total energy (K.E. + P.E.) = E_0 . Its potential energy is

- (a) $-E_0$ (b) $1.5E_0$
 (c) $2E_0$ (d) E_0



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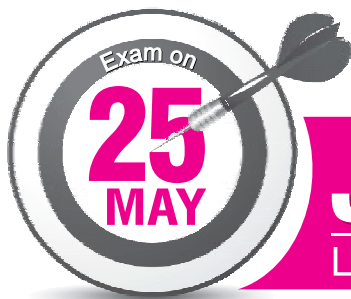
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JEE FINAL TOUCH

Last 3 Years Chapterwise Questions

CLASS-11

UNITS AND DIMENSIONS

- Using the expression $2d\sin\theta = \lambda$, one calculates the values of d by measuring the corresponding angles θ in the range 0 to 90° . The wavelength λ is exactly known and the error in θ is constant for all values of θ . As θ increases from 0° ,
 - the absolute error in d remains constant.
 - the absolute error in d increases.
 - the fractional error in d remains constant.
 - the fractional error in d decreases. (2013)
- Match List I with List II and select the correct answer using the codes given below the lists:

| | List I | | List II |
|----|--------------------------|----|----------------------|
| P. | Boltzmann constant | 1. | $[ML^2T^{-1}]$ |
| Q. | Coefficient of viscosity | 2. | $[ML^{-1}T^{-1}]$ |
| R. | Planck constant | 3. | $[MLT^{-3}K^{-1}]$ |
| S. | Thermal conductivity | 4. | $[ML^2T^{-2}K^{-1}]$ |

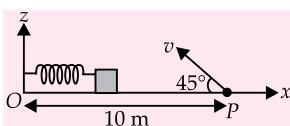
Codes :

| | | | | |
|-----|---|---|---|---|
| | P | Q | R | S |
| (a) | 3 | 1 | 2 | 4 |
| (b) | 3 | 2 | 1 | 4 |
| (c) | 4 | 2 | 1 | 3 |
| (d) | 4 | 1 | 2 | 3 |

(2013)

MOTION IN A PLANE

- A small block is connected to one end of a massless spring of un-stretched length 4.9 m. The other end of the spring (see the figure) is fixed. The system lies on a horizontal frictionless surface. The block is stretched by 0.2 m and released from rest at $t=0$. It then executes simple harmonic motion with angular frequency $\omega = \frac{\pi}{3}$ rad/s. Simultaneously at $t=0$, a small pebble is projected with speed v from point P at an angle of 45° as shown in the figure. Point P is at a horizontal distance of



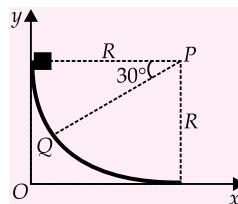
10 m from O . If the pebble hits the block at $t=1$ s, the value of v is (Take $g=10$ m/s²)

- $\sqrt{50}$ m/s
- $\sqrt{51}$ m/s
- $\sqrt{52}$ m/s
- $\sqrt{53}$ m/s (2012)

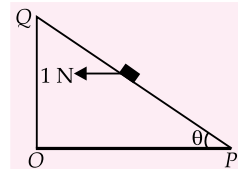
LAWS OF MOTION

Paragraph for Questions 4 and 5

A small block of mass 1 kg is released from rest at the top of a rough track. The track is a circular arc of radius 40 m. The block slides along the track without toppling and a frictional force acts on it in the direction opposite to the instantaneous velocity. The work done in overcoming the friction up the point Q , as shown in the figure below, is 150 J. (Take the acceleration due to gravity, $g=10$ m/s²)



- The magnitude of the normal reaction that acts on the block at the point Q is
 - 7.5 N
 - 8.6 N
 - 11.5 N
 - 22.5 N
- The speed of the block when it reaches the point Q is
 - 5 ms⁻¹
 - 10 ms⁻¹
 - $10\sqrt{3}$ ms⁻¹
 - 20 ms⁻¹ (2013)
- A small block of mass of 0.1 kg lies on a fixed inclined plane PQ which makes an angle θ with the horizontal. A horizontal force of 1 N acts on the block through its center of mass as shown in the figure. The block remains stationary if (take $g=10$ m/s²)
 - $\theta=45^\circ$
 - $\theta>45^\circ$ and a frictional force acts on the block towards P .
 - $\theta>45^\circ$ and a frictional force acts on the block towards Q .
 - $\theta<45^\circ$ and a frictional force acts on the block towards Q . (2012)



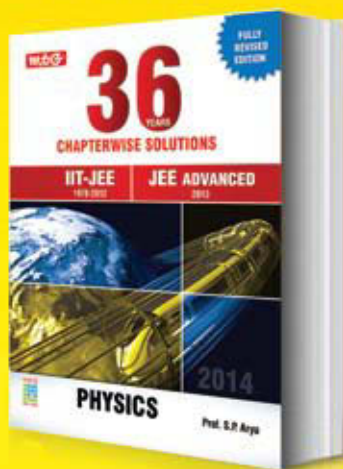
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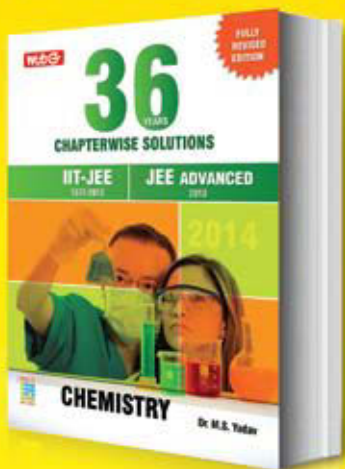
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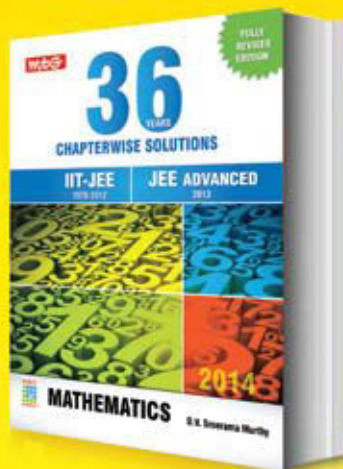
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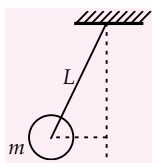


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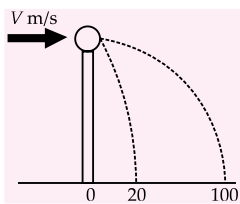
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7. A ball of mass (m) 0.5 kg is attached to the end of a string having length (L) 0.5 m. The ball is rotated on a horizontal circular path about vertical axis. The maximum tension that the string can bear is 324 N. The maximum possible value of angular velocity of ball (in radian/s) is
- (a) 9 (b) 18
(c) 27 (d) 36 (2011)



8. A block is moving on an inclined plane making an angle 45° with the horizontal and the coefficient of friction is μ . The force required to just push it up the inclined plane is 3 times the force required to just prevent it from sliding down. If we define $N = 10\mu$, then N is (Integer Answer Type, 2011)

9. A ball of mass 0.2 kg rests on a vertical post of height 5 m. A bullet of mass 0.01 kg, travelling with a velocity V m/s in a horizontal direction, hits the centre of the ball. After the collision, the ball and bullet travel independently. The ball hits the ground at a distance of 20 m and the bullet at a distance of 100 m from the foot of the post. The initial velocity V of the bullet is
- (a) 250 m/s (b) $250\sqrt{2}$ m/s
(c) 400 m/s (d) 500 m/s (2011)



WORK, ENERGY AND POWER

10. The work done on a particle of mass m by a force, $K \left[\frac{x}{(x^2 + y^2)^{3/2}} \hat{i} + \frac{y}{(x^2 + y^2)^{3/2}} \hat{j} \right]$ (K being a constant of appropriate dimensions), when the particle is taken from the point $(a, 0)$ to the point $(0, a)$ along a circular path of radius a about the origin in the x - y plane is
- (a) $\frac{2K\pi}{a}$ (b) $\frac{K\pi}{a}$
(c) $\frac{K\pi}{2a}$ (d) 0 (2013)
11. A particle of mass m is projected from the ground with an initial speed u_0 at an angle α with the horizontal. At the highest point of its trajectory, it makes a completely inelastic collision with another identical particle, which was thrown vertically upward from the ground with the same initial speed u_0 . The angle that the composite system makes with the horizontal immediately after the collision is

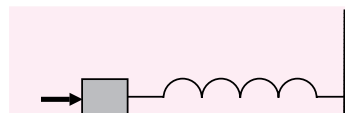
- (a) $\frac{\pi}{4}$ (b) $\frac{\pi}{4} + \alpha$
(c) $\frac{\pi}{2} - \alpha$ (d) $\frac{\pi}{2}$ (2013)

12. A pulse of light of duration 100 ns is absorbed completely by a small object initially at rest. Power of the pulse is 30 mW and the speed of light is 3×10^8 ms $^{-1}$. The final momentum of the object is
- (a) 0.3×10^{-17} kg ms $^{-1}$ (b) 1.0×10^{-17} kg ms $^{-1}$
(c) 3.0×10^{-17} kg ms $^{-1}$ (d) 9.0×10^{-17} kg ms $^{-1}$ (2013)

13. A bob of mass m , suspended by a string of length l_1 is given a minimum velocity required to complete a full circle in the vertical plane. At the highest point, it collides elastically with another bob of mass m suspended by a string of length l_2 , which is initially at rest. Both the strings are mass-less and inextensible. If the second bob, after collision acquires the minimum speed required to complete a full circle in the vertical plane, the ratio $\frac{l_1}{l_2}$ is (Integer Answer Type, 2013)

14. A particle of mass 0.2 kg is moving in one dimension under a force that delivers a constant power 0.5 W to the particle. If the initial speed (in ms $^{-1}$) of the particle is zero, the speed (in ms $^{-1}$) after 5 s is (Integer Answer Type, 2013)

15. A block of mass 0.18 kg is attached to a spring of force-constant 2 N/m. The coefficient of friction between the block and the floor is 0.1. Initially the block is at rest and the spring is unstretched. An impulse is given to the block as shown in the figure. The block slides a distance of 0.06 m and comes to rest for the first time. The initial velocity of the block in m/s is $V = N/10$. Then N is (Integer Answer Type, 2011)



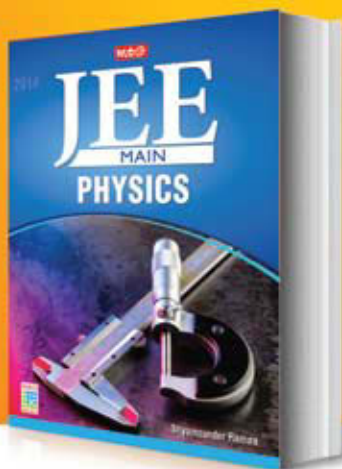
SYSTEM OF PARTICLES AND ROTATIONAL MOTION

16. A uniform circular disc of mass 50 kg and radius 0.4 m is rotating with an angular velocity of 10 rad s $^{-1}$ about its own axis, which is vertical. Two uniform circular rings, each of mass 6.25 kg and radius 0.2 m, are gently placed symmetrically on the disc in such a manner that they are touching each other along the axis of the disc and are horizontal. Assume that the friction is large enough such that the rings are at rest relative to the disc and the system rotates about the original axis. The new angular velocity (in rad s $^{-1}$) of the system is (Integer Answer Type, 2013)

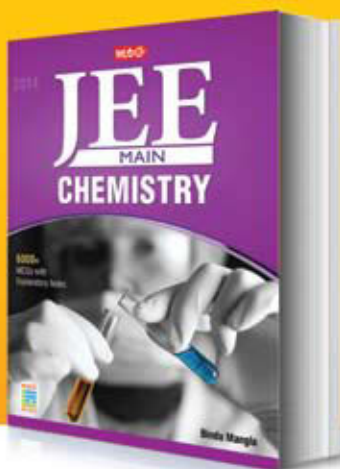
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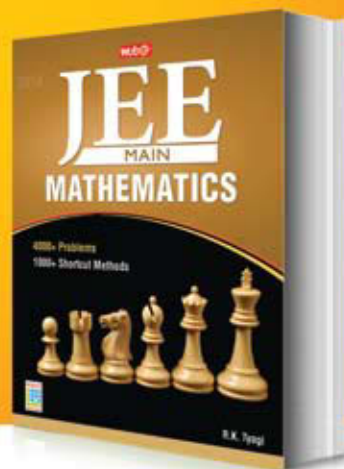
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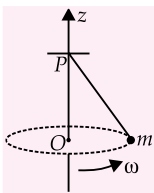
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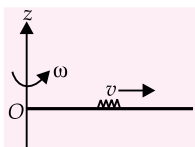


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17. A small mass m is attached to a massless string whose other end is fixed at P as shown in the figure. The mass is undergoing circular motion in the x - y plane with centre at O and constant angular speed ω . If the angular momentum of the system, calculated about O and P are denoted by \vec{L}_O and \vec{L}_P respectively, then
- (a) \vec{L}_O and \vec{L}_P do not vary with time.
 (b) \vec{L}_O varies with time while \vec{L}_P remains constant.
 (c) \vec{L}_O remains constant while \vec{L}_P varies with time.
 (d) \vec{L}_O and \vec{L}_P both vary with time. (2012)

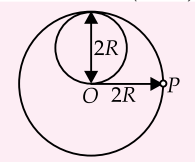


18. A thin uniform rod, pivoted at O , is rotating in the horizontal plane with constant angular speed ω , as shown in the figure. At time $t = 0$, a small insect starts from O and moves with constant speed v with respect to the rod towards other end. It reaches the end of the rod at $t = T$ and stops. The angular speed of the system remains ω throughout. The magnitude of the torque ($|\vec{\tau}|$) on the system about O , as a function of time is best represented by which plot?



- (a) (b) (c) (d) (2012)

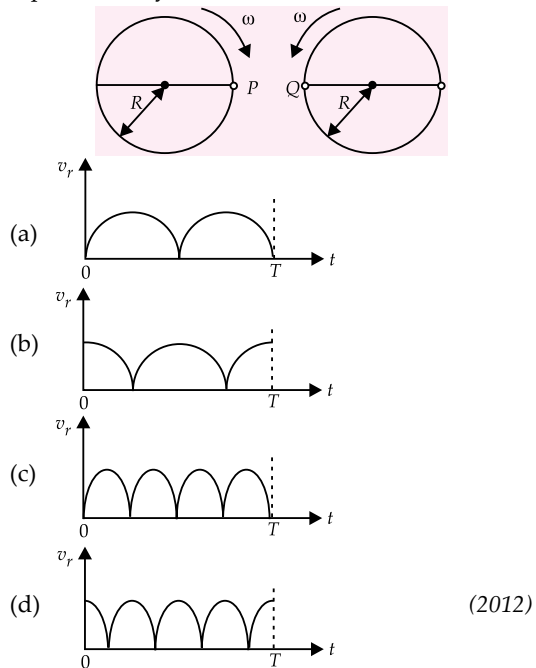
19. A lamina is made by removing a small disc of diameter $2R$ from a bigger disc of uniform mass density and radius $2R$, as shown in the figure. The moment of inertia of this lamina about axes passing through O and P is I_O and I_P respectively. Both these axes are perpendicular to the plane of the lamina. The ratio $\frac{I_P}{I_O}$ to the nearest integer is



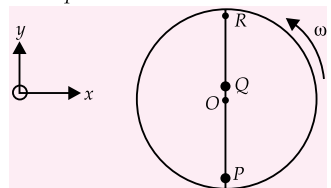
(Integer Answer Type, 2012)

20. Two identical discs of same radius R are rotating about their axes in opposite directions with the same constant angular speed ω . The discs are

in the same horizontal plane. At time $t = 0$, the points P and Q are facing each other as shown in the figure. The relative speed between the two points P and Q is v_r . In one time period (T) of rotation of the discs, v_r as a function of time is best represented by



21. Consider a disc rotating in the horizontal plane with a constant angular speed ω about its centre O . The disc has a shaded region on one side of the diameter and an unshaded region on the other side as shown in the figure.

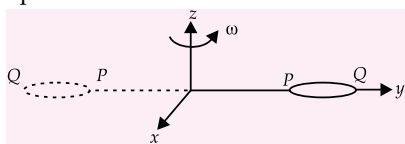


When the disc is in the orientation as shown, two pebbles P and Q are simultaneously projected at an angle towards R . The velocity of projection is in the y - z plane and is same for both pebbles with respect to the disc. Assume that (i) they land back

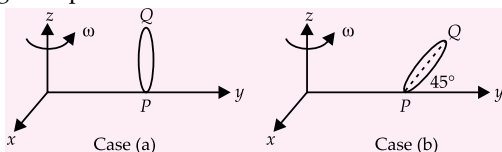
- on the disc before the disc has completed $\frac{1}{8}$ rotation,
 (ii) their range is less than half the disc radius, and
 (iii) ω remains constant throughout. Then
 (a) P lands in the shaded region and Q in the unshaded region
 (b) P lands in the unshaded region and Q in the shaded region
 (c) both P and Q land in the unshaded region
 (d) both P and Q land in the shaded region (2012)

Paragraph for Questions 22 and 23

The general motion of a rigid body can be considered to be a combination of (i) a motion of its centre of mass about an axis, and (ii) its motion about an instantaneous axis passing through the centre of mass. These axes need not be stationary. Consider, for example, a thin uniform disc welded (rigidly fixed) horizontally at its rim to a massless stick, as shown in the figure. When the disc-stick system is rotated about the origin on a horizontal frictionless plane with angular speed ω , the motion at any instant can be taken as a combination of (i) a rotation of the centre of mass of the disc about the z -axis, and (ii) a rotation of the disc through an instantaneous vertical axis passing through its centre of mass (as is seen from the changed orientation of points P and Q). Both these motions have the same angular speed ω in this case.

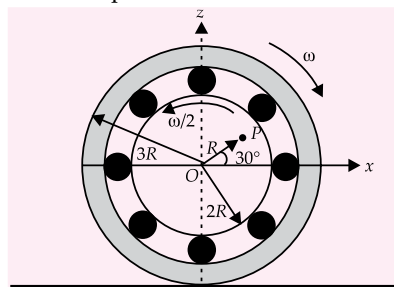


Now consider two similar systems as shown in the figure: Case (a) the disc with its face vertical and parallel to x - z plane; Case (b) the disc with its face making an angle of 45° with x - y plane and its horizontal diameter parallel to x -axis. In both the cases, the disc is welded at point P , and the systems are rotated with constant angular speed ω about the z -axis.

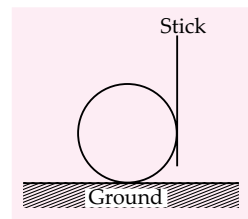


22. Which of the following statements about the instantaneous axis (passing through the same centre of mass) is correct?
- It is vertical for both the cases (a) and (b).
 - It is vertical for case (a); and is at 45° to the x - z plane and lies in the plane of the disc for case (b).
 - It is horizontal for case (a); and is at 45° to the x - z plane and is normal to the plane of the disc for case (b).
 - It is vertical for case (a); and is at 45° to the x - z plane and is normal to the plane of the disc for case (b).
23. Which of the following statements regarding the angular speed about the instantaneous axis (passing through the centre of mass) is correct?
- It is $\sqrt{2}\omega$ for both the cases.
 - It is ω for case (a); and $\frac{\omega}{\sqrt{2}}$ for case (b).
 - It is ω for case (a); and $\sqrt{2}\omega$ for case (b).
 - It is ω for both the cases. (2012)

24. The figure shows a system consisting of (i) a ring of outer radius $3R$ rolling clockwise without slipping on a horizontal surface with angular speed ω and (ii) an inner disc of radius $2R$ rotating anti-clockwise with angular speed $\omega/2$. The ring and disc are separated by frictionless ball bearings. The system is in the x - z plane. The point P on the inner disc is at a distance R from the origin, where OP makes an angle of 30° with the horizontal. Then with respect to the horizontal surface,



- the point O has a linear velocity $3R\omega \hat{i}$
 - the point P has a linear velocity $\frac{11}{4}R\omega \hat{i} + \frac{\sqrt{3}}{4}R\omega \hat{k}$
 - the point P has a linear velocity $\frac{13}{4}R\omega \hat{i} - \frac{\sqrt{3}}{4}R\omega \hat{k}$
 - the point P has a linear velocity $\left(3 - \frac{\sqrt{3}}{4}\right)R\omega \hat{i} + \frac{1}{4}R\omega \hat{k}$ (2012)
25. Two solid cylinders P and Q of same mass and same radius start rolling down a fixed inclined plane from the same height at the same time. Cylinder P has most of its mass concentrated near its surface, while Q has most of its mass concentrated near the axis. Which statement(s) is(are) correct?
- Both cylinders P and Q reach the ground at the same time.
 - Cylinder P has larger linear acceleration than cylinder Q .
 - Both cylinders reach the ground with same translational kinetic energy.
 - Cylinder Q reaches the ground with larger angular speed. (2012)
26. A boy is pushing a ring of mass 2 kg and radius 0.5 m with a stick as shown in the figure. The stick applies a force of 2 N on the ring and rolls it without slipping with an acceleration of 0.3 m/s^2 .



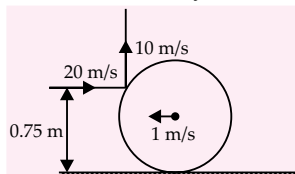
The coefficient of friction between the ground and the ring is large enough that rolling always occurs and the coefficient of friction between the stick and the ring is $(P/10)$. The value of P is

(Integer Answer Type, 2011)

27. Four solid spheres each of diameter $\sqrt{5}$ cm and mass 0.5 kg are placed with their centers at the corners of a square of side 4 cm. The moment of inertia of the system about the diagonal of the square is $N \times 10^{-4} \text{ kg-m}^2$, then N is

(Integer Answer Type, 2011)

28. A thin ring of mass 2 kg and radius 0.5 m is rolling without slipping on a horizontal plane with velocity 1 m/s. A small ball of mass 0.1 kg, moving with velocity 20 m/s in the opposite direction, hits the ring at a height of 0.75 m and goes vertically up with velocity 10 m/s. Immediately after the collision



- (a) the ring has pure rotation about its stationary CM.
 (b) the ring comes to a complete stop.
 (c) friction between the ring and the ground is to the left.
 (d) there is no friction between the ring and the ground. (2011)

GRAVITATION

29. Two bodies, each of mass M , are kept fixed with a separation $2L$. A particle of mass m is projected from the midpoint of the line joining their centres, perpendicular to the line. The gravitational constant is G . The correct statement(s) is (are)
- (a) The minimum initial velocity of the mass m to escape the gravitational field of the two bodies is $4\sqrt{\frac{GM}{L}}$.
 (b) The minimum initial velocity of the mass m to escape the gravitational field of the two bodies is $2\sqrt{\frac{GM}{L}}$.
 (c) The minimum initial velocity of the mass m to escape the gravitational field of the two bodies is $\sqrt{\frac{2GM}{L}}$.
 (d) The energy of the mass m remains constant. (2013)
30. Two spherical planets P and Q have the same uniform density ρ , masses M_P and M_Q , and

surface areas A and $4A$, respectively. A spherical planet R also has uniform density ρ and its mass is $(M_P + M_Q)$. The escape velocities from the planets P , Q and R are V_P , V_Q and V_R , respectively. Then

- (a) $V_Q > V_R > V_P$ (b) $V_R > V_Q > V_P$
 (c) $\frac{V_R}{V_P} = 3$ (d) $\frac{V_P}{V_Q} = \frac{1}{2}$ (2012)

31. A satellite is moving with a constant speed V in a circular orbit about the earth. An object of mass m is ejected from the satellite such that it just escapes from the gravitational pull of the earth. At the time of its ejection, the kinetic energy of the object is

- (a) $\frac{1}{2}mV^2$ (b) mV^2
 (c) $\frac{3}{2}mV^2$ (d) $2mV^2$ (2011)

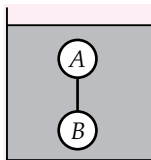
MECHANICAL PROPERTIES OF SOLIDS

32. One end of a horizontal thick copper wire of length $2L$ and radius $2R$ is welded to an end of another horizontal thin copper wire of length L and radius R . When the arrangement is stretched by applying forces at two ends, the ratio of the elongation in the thin wire to that in the thick wire is
- (a) 0.25 (b) 0.50
 (c) 2.00 (d) 4.00 (2013)

MECHANICAL PROPERTIES OF FLUIDS

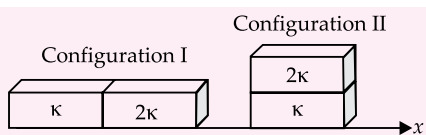
33. A solid sphere of radius R and density ρ is attached to one end of a mass-less spring of force constant k . The other end of the spring is connected to another solid sphere of radius R and density 3ρ . The complete arrangement is placed in a liquid of density 2ρ and is allowed to reach equilibrium. The correct statement(s) is (are)
- (a) the net elongation of the spring is $\frac{4\pi R^3 \rho g}{3k}$.
 (b) the net elongation of the spring is $\frac{8\pi R^3 \rho g}{3k}$.
 (c) the light sphere is partially submerged.
 (d) the light sphere is completely submerged. (2013)
34. A thin uniform cylindrical shell, closed at both ends, is partially filled with water. It is floating vertically in water in half-submerged state. If ρ_c is the relative density of the material of the shell with respect to water, then the correct statement is that the shell is
- (a) more than half-filled if ρ_c is less than 0.5
 (b) more than half-filled if ρ_c is more than 1.0
 (c) half-filled if ρ_c more than 0.5
 (d) less than half-filled if ρ_c is less than 0.5 (2012)

35. Two solid spheres A and B of equal volumes but of different densities d_A and d_B are connected by a string. They are fully immersed in a fluid of density d_F . They get arranged into an equilibrium state as shown in the figure with a tension in the string. The arrangement is possible only if
- (a) $d_A < d_F$ (b) $d_B > d_F$
 (c) $d_A > d_F$ (d) $d_A + d_B = 2d_F$ (2011)

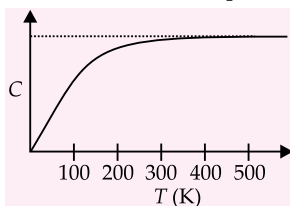


THERMAL PROPERTIES OF MATTER

36. Two rectangular blocks, having identical dimensions, can be arranged either in configuration I or in configuration II as shown in the figure. One of the blocks has thermal conductivity κ and the other 2κ . The temperature difference between the ends along the x -axis is the same in both the configurations. It takes 9 s to transport a certain amount of heat from the hot end to the cold end in the configuration I. The time to transport the same amount of heat in the configuration II is



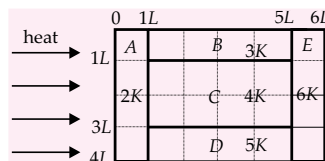
- (a) 2.0 s (b) 3.0 s
 (c) 4.5 s (d) 6.0 s (2013)
37. The figure below shows the variation of specific heat capacity (C) of a solid as a function of temperature (T). The temperature is increased continuously from 0 to 500 K at a constant rate. Ignoring any volume change, the following statement(s) is (are) correct to a reasonable approximation.
- (a) The rate at which heat is absorbed in the range 0-100 K varies linearly with temperature T .
 (b) Heat absorbed in increasing the temperature from 0-100 K is less than the heat required for increasing the temperature from 400-500 K.
 (c) There is no change in the rate of heat absorption in the range 400-500 K.
 (d) The rate of heat absorption increases in the range 200-300 K. (2013)



38. Three very large plates of same area are kept parallel and close to each other. They are considered as ideal black surfaces and have very high thermal conductivity. The first and third plates are maintained at temperatures $2T$ and $3T$ respectively. The temperature of the middle (i.e. second) plate under steady state condition is

- (a) $\left(\frac{65}{2}\right)^{1/4} T$ (b) $\left(\frac{97}{4}\right)^{1/4} T$
 (c) $\left(\frac{97}{2}\right)^{1/4} T$ (d) $(97)^{1/4} T$ (2012)

39. A composite block is made of slabs A , B , C , D and E of different thermal conductivities (given in terms of a constant K) and sizes (given in terms of length, L) as shown in the figure. All slabs are of same width. Heat Q flows only from left to right through the blocks. Then in steady state
- (a) heat flow through A and E slabs are same.
 (b) heat flow through slab E is maximum.
 (c) temperature difference across slab E is smallest.
 (d) heat flow through $C = \text{heat flow through } B + \text{heat flow through } D$. (2011)



40. Steel wire of length L at 40°C is suspended from the ceiling and then a mass m is hung from its free end. The wire is cooled down from 40°C to 30°C to regain its original length L . The coefficient of linear thermal expansion of the steel is $10^{-5}/^\circ\text{C}$, Young's modulus of steel is 10^{11} N/m^2 and radius of the wire is 1 mm. Assume that $L \gg$ diameter of the wire. Then the value of m in kg is nearly
 (Integer Answer Type, 2011)

THERMODYNAMICS

41. Two moles of ideal helium gas are in a rubber balloon at 30°C . The balloon is fully expandable and can be assumed to require no energy in its expansion. The temperature of the gas in the balloon is slowly changed to 35°C . The amount of heat required in raising the temperature is nearly (Take $R = 8.31 \text{ J/mol.K}$)
- (a) 62 J (b) 104 J
 (c) 124 J (d) 208 J (2012)
42. 5.6 liter of helium gas at STP is adiabatically compressed to 0.7 liter. Taking the initial temperature to be T_1 , the work done in the process is
- (a) $\frac{9}{8} RT_1$ (b) $\frac{3}{2} RT_1$
 (c) $\frac{15}{8} RT_1$ (d) $\frac{9}{2} RT_1$ (2011)

KINETIC THEORY

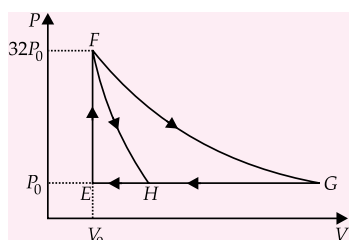
43. Two non-reactive monoatomic ideal gases have their atomic masses in the ratio 2 : 3. The ratio of their partial pressures, when enclosed in a vessel kept at a constant temperature, is 4 : 3. The ratio

of their densities is

- (a) 1 : 4 (b) 1 : 2
(c) 6 : 9 (d) 8 : 9 (2013)

44. One mole of a monatomic ideal gas is taken along two cyclic processes $E \rightarrow F \rightarrow G \rightarrow E$ and $E \rightarrow F \rightarrow H \rightarrow E$ as shown in the PV diagram. The processes involved are purely isochoric, isobaric, isothermal or adiabatic.

Match the paths in List I with the magnitudes of the work done in List II and select the correct answer using the codes given below the lists.



| | List I | | List II |
|----|-------------------|----|---------------------|
| P. | $G \rightarrow E$ | 1. | $160 P_0 V_0 \ln 2$ |
| Q. | $G \rightarrow H$ | 2. | $36 P_0 V_0$ |
| R. | $F \rightarrow H$ | 3. | $24 P_0 V_0$ |
| S. | $F \rightarrow G$ | 4. | $31 P_0 V_0$ |

Codes :

| | | | | |
|-----|---|---|---|---|
| | P | Q | R | S |
| (a) | 4 | 3 | 2 | 1 |
| (b) | 4 | 3 | 1 | 2 |
| (c) | 3 | 1 | 2 | 4 |
| (d) | 1 | 3 | 2 | 4 |

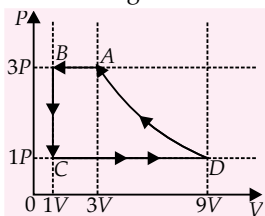
(2013)

45. A mixture of 2 moles of helium gas (atomic mass = 4 amu) and 1 mole of argon gas (atomic mass = 40 amu) is kept at 300 K in a container. The

ratio of the rms speeds $\left(\frac{v_{\text{rms}}(\text{helium})}{v_{\text{rms}}(\text{argon})} \right)$ is

- (a) 0.32 (b) 0.45
(c) 2.24 (d) 3.16 (2012)

46. One mole of a monatomic ideal gas is taken through a cycle $ABCD$ as shown in the $P-V$ diagram. Column II gives the characteristics involved in the cycle. Match them with each of the processes given in column I.



| | Column I | | Column II |
|-----|---------------------------|-----|----------------------------|
| (A) | Process $A \rightarrow B$ | (p) | Internal energy decreases. |
| (B) | Process $B \rightarrow C$ | (q) | Internal energy increases. |
| (C) | Process $C \rightarrow D$ | (r) | Heat is lost. |
| (D) | Process $D \rightarrow A$ | (s) | Heat is gained. |
| | | (t) | Work is done on the gas. |

(2011)

OSCILLATIONS

47. A particle of mass m is attached to one end of a mass-less spring of force constant k , lying on a frictionless horizontal plane. The other end of the spring is fixed. The particle starts moving horizontally from its equilibrium position at time $t = 0$ with an initial velocity u_0 . When the speed of the particle is $0.5u_0$, it collides elastically with a rigid wall. After this collision,

- (a) the speed of the particle when it returns to its equilibrium position is u_0 .
(b) the time at which the particle passes through the equilibrium position for the first time is

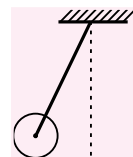
$$t = \pi \sqrt{\frac{m}{k}}.$$

- (c) the time at which the maximum compression of the spring occurs is $t = \frac{4\pi}{3} \sqrt{\frac{m}{k}}.$

- (d) the time at which the particle passes through the equilibrium position for the second time

$$\text{is } t = \frac{5\pi}{3} \sqrt{\frac{m}{k}}. \quad (2013)$$

48. A metal rod of length L and mass m is pivoted at one end. A thin disk of mass M and radius R ($< L$) is attached at its center to the free end of the rod.

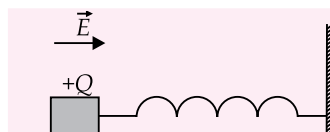


Consider two ways the disc is attached : (case A) The disc is not free to rotate about its center and (case B) the disc is free to rotate about its center. The rod-disk system perform SHM in vertical plane after being released from the same displaced position. Which of the following statement(s) is (are) true?

- (a) Restoring torque in case A = Restoring torque in case B
(b) Restoring torque in case A < Restoring torque in case B
(c) Angular frequency for case A > Angular frequency for case B
(d) Angular frequency for case A < Angular frequency for case B

(2011)

49. A wooden block performs SHM on a frictionless surface with frequency, ν_0 . The block carries



a charge $+Q$ on its surface. If now a uniform electric field \vec{E} is switched on as shown, then the SHM of the block will be

- (a) of the same frequency and with shifted mean position.
 (b) of the same frequency and with the same mean position.
 (c) of changed frequency and with shifted mean position.
 (d) of changed frequency and with the same mean position. (2011)

WAVES

50. A horizontal stretched string, fixed at two ends, is vibrating in its fifth harmonic according to the equation,
 $y(x, t) = (0.01 \text{ m}) \sin[(62.8 \text{ m}^{-1})x] \cos[(628 \text{ s}^{-1})t]$.
 Assuming $\pi = 3.14$, the correct statement(s) is (are)
 (a) The number of nodes is 5.
 (b) The length of the string is 0.25 m.
 (c) The maximum displacement of the midpoint of the string, from its equilibrium position is 0.01 m.
 (d) The fundamental frequency is 100 Hz. (2013)
51. Two vehicles, each moving with speed u on the same horizontal straight road, are approaching each other. Wind blows along the road with velocity w . One of these vehicles blows a whistle of frequency f_1 . An observer in the other vehicle hears the frequency of the whistle to be f_2 . The speed of sound in still air is V . The correct statement(s) is (are)
 (a) If the wind blows from the observer to the source, $f_2 > f_1$.
 (b) If the wind blows from the source to the observer, $f_2 > f_1$.
 (c) If the wind blows from observer to the source, $f_2 < f_1$.
 (d) If the wind blows from the source to the observer, $f_2 < f_1$. (2013)
52. A person blows into open-end of a long pipe. As a result, a high-pressure pulse of air travels down the pipe. When this pulse reaches the other end of the pipe,
 (a) a high-pressure pulse starts traveling up the pipe, if the other end of the pipe is open.
 (b) a low-pressure pulse starts traveling up the pipe, if the other end of the pipe is open.
 (c) a low-pressure pulse starts traveling up the pipe, if the other end of the pipe is closed.
 (d) a high-pressure pulse starts traveling up the pipe, if the other end of the pipe is closed. (2012)

53. A student is performing the experiment of Resonance Column. The diameter of the column tube is 4 cm. The frequency of the tuning fork is 512 Hz. The air temperature is 38°C in which the speed of sound is 336 m/s. The zero of the meter

scale coincides with the top end of the Resonance Column tube. When the first resonance occurs, the reading of the water level in the column is

- (a) 14.0 cm (b) 15.2 cm
 (c) 16.4 cm (d) 17.6 cm (2012)

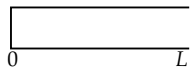
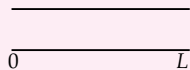
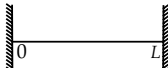
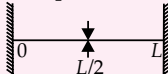
54. A police car with a siren of frequency 8 kHz is moving with uniform velocity 36 km/hr towards a tall building which reflects the sound waves. The speed of sound in air is 320 m/s. The frequency of the siren heard by the car driver is
 (a) 8.50 kHz (b) 8.25 kHz
 (c) 7.75 kHz (d) 7.50 kHz (2011)

55. A point mass is subjected to two simultaneous sinusoidal displacements in x -direction,
 $x_1(t) = A \sin \omega t$ and $x_2(t) = A \sin \left(\omega t + \frac{2\pi}{3} \right)$.

Adding a third sinusoidal displacement $x_3(t) = B \sin(\omega t + \phi)$ brings the mass to a complete rest. The values of B and ϕ are

- (a) $\sqrt{2}A, \frac{3\pi}{4}$ (b) $A, \frac{4\pi}{3}$
 (c) $\sqrt{3}A, \frac{5\pi}{6}$ (d) $A, \frac{\pi}{3}$ (2011)

56. Column I shows four systems, each of the same length L , for producing standing waves. The lowest possible natural frequency of a system is called its fundamental frequency, whose wavelength is denoted as λ_f . Match each system with statements given in Column II describing the nature and wavelength of the standing waves.

| | Column I | | Column II |
|-----|---|-----|--------------------|
| (A) | Pipe closed at one end  | (p) | Longitudinal waves |
| (B) | Pipe open at both ends  | (q) | Transverse waves |
| (C) | Stretched wire clamped at both ends  | (r) | $\lambda_f = L$ |
| (D) | Stretched wire clamped at both ends and at mid-point  | (s) | $\lambda_f = 2L$ |
| | | (t) | $\lambda_f = 4L$ |

(2011)

SOLUTIONS

1. (d)

2. (c)

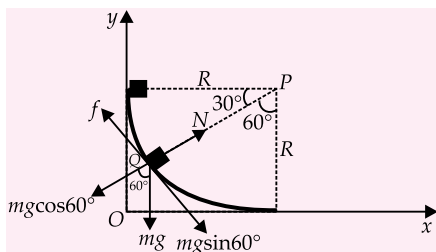
3. (a): Time of flight for projectile

$$T = \frac{2v \sin \theta}{g} \Rightarrow 1 = \frac{2v \sin 45^\circ}{g}$$

$$\text{or } v = \frac{g}{2 \sin 45^\circ} = \frac{g}{2 \left(\frac{1}{\sqrt{2}} \right)} = \frac{g}{\sqrt{2}} = \frac{10}{\sqrt{2}}$$

$$= 5\sqrt{2} = \sqrt{50} \text{ m/s}$$

4. (a): The various forces acting on the block is as shown in the figure.



$$N - mg \cos 60^\circ = \frac{mv^2}{R}, N = \frac{mv^2}{R} + mg \cos 60^\circ$$

$$\text{Here, } m = 1 \text{ kg, } R = 40 \text{ m, } g = 10 \text{ m s}^{-2}, v = 10 \text{ m s}^{-1}$$

$$\therefore N = \frac{(1 \text{ kg})(10 \text{ m s}^{-1})^2}{40 \text{ m}} + (1 \text{ kg})(10 \text{ m s}^{-2}) \frac{1}{2}$$

$$= 2.5 \text{ N} + 5 \text{ N} = 7.5 \text{ N}$$

5. (b): Let v be speed of the block at C .

According to work-energy theorem

$$W_g + W_f = \Delta K$$

$$Mg \frac{R}{2} - 150 = \frac{1}{2} mv^2 \quad (\because u = 0)$$

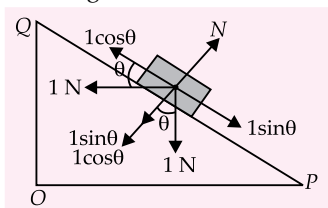
$$1 \times 10 \times \frac{40}{2} - 150 = \frac{1}{2} \times 1 \times v^2$$

$$200 - 150 = \frac{1}{2} v^2 \Rightarrow v^2 = 100 \text{ or } v = 10 \text{ m s}^{-1}$$

6. (a, c): Here, $m = 0.1 \text{ kg}$, $g = 10 \text{ m s}^{-2}$

$$\therefore mg = 0.1 \times 10 = 1 \text{ N}$$

The various forces acting on the block are as shown in the figure.



If $\theta = 45^\circ$, then

$$\cos \theta = \sin \theta$$

If plane is rough and $\theta > 45^\circ$, then

$$\sin \theta > \cos \theta$$

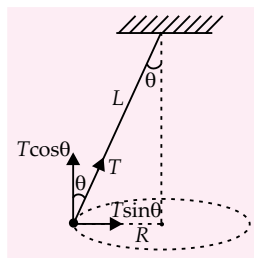
So frictional force acts on the block towards Q .

If plane is rough and $\theta < 45^\circ$, then

$$\cos \theta > \sin \theta$$

So frictional force acts on the block towards P .

7. (d):



From figure,

$$R = L \sin \theta$$

The horizontal component provides the centripetal force.

$$\therefore T \sin \theta = m \omega^2 R$$

$$T \sin \theta = m \omega^2 L \sin \theta$$

$$T = m \omega^2 L$$

$$\omega = \sqrt{\frac{T}{mL}}$$

Substituting the given values, we get

$$\omega = \sqrt{\frac{324}{0.5 \times 0.5}} = 36 \text{ rad/s}$$

8. (5): Force required to push the block up the inclined plane is

$$F_u = mg \sin \theta + \mu mg \cos \theta \quad \dots(i)$$

Force required to just prevent the block from sliding down is

$$F_d = mg \sin \theta - \mu mg \cos \theta \quad \dots(ii)$$

According to the problem

$$F_u = 3F_d$$

$$\therefore mg \sin \theta + \mu mg \cos \theta = 3(mg \sin \theta - \mu mg \cos \theta)$$

$$\text{or } \sin \theta + \mu \cos \theta = 3(\sin \theta - \mu \cos \theta)$$

$$\frac{1}{\sqrt{2}} + \frac{\mu}{\sqrt{2}} = 3 \left(\frac{1}{\sqrt{2}} - \frac{\mu}{\sqrt{2}} \right) \quad (\because \theta = 45^\circ \text{ (Given)})$$

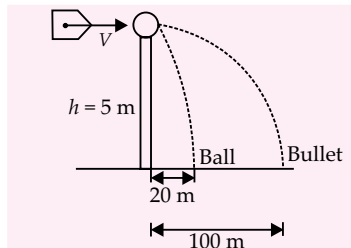
$$1 + \mu = 3 - 3\mu$$

$$4\mu = 2 \text{ or } \mu = \frac{1}{2}$$

$$N = 10\mu$$

$$\therefore N = 10 \times \frac{1}{2} = 5$$

9. (d):



Time of flight,

$$T_{\text{flight}} = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 5 \text{ m}}{10 \text{ m/s}^2}} = 1 \text{ s}$$

Final velocity of the bullet after collision,

$$v_{\text{bullet}} = \frac{100 \text{ m}}{1 \text{ s}} = 100 \text{ m/s}$$

Final velocity of the ball after collision,

$$v_{\text{ball}} = \frac{20 \text{ m}}{1 \text{ s}} = 20 \text{ m/s}$$

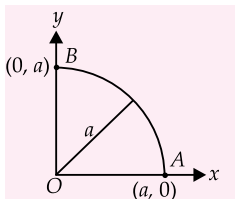
According to law of conservation of linear momentum, we get

$$m_{\text{ball}} \times 0 + m_{\text{bullet}} \times V = m_{\text{ball}} \times v_{\text{ball}} + m_{\text{bullet}} \times v_{\text{bullet}}$$

$$0.01V = 0.2 \times 20 + 0.01 \times 100$$

$$V = 500 \text{ m/s}$$

10. (d):



$$\vec{F} = K \left[\frac{x}{(x^2 + y^2)^{3/2}} \hat{i} + \frac{y}{(x^2 + y^2)^{3/2}} \hat{j} \right]$$

Let $\vec{r} = x\hat{i} + y\hat{j}$

$$\therefore d\vec{r} = dx\hat{i} + dy\hat{j}$$

$$\text{and } r = \sqrt{x^2 + y^2}$$

Work done by the force \vec{F} in moving a particle from A to B is

$$\begin{aligned} W &= \int_{r_A}^{r_B} \vec{F} \cdot d\vec{r} \\ &= \int_{r_A}^{r_B} K \left[\frac{x\hat{i}}{(x^2 + y^2)^{3/2}} + \frac{y\hat{j}}{(x^2 + y^2)^{3/2}} \right] \cdot (dx\hat{i} + dy\hat{j}) \\ &= K \int_{r_A}^{r_B} \frac{xdx}{(x^2 + y^2)^{3/2}} + \frac{ydy}{(x^2 + y^2)^{3/2}} \\ &= K \int_{r_A}^{r_B} \frac{1}{(x^2 + y^2)^{3/2}} \left\{ d\left(\frac{x^2}{2}\right) + d\left(\frac{y^2}{2}\right) \right\} \\ &= K \int_{r_A}^{r_B} \frac{1}{2(x^2 + y^2)^{3/2}} d(x^2 + y^2) \\ &= K \int_{r_A}^{r_B} \frac{1}{2r^3} d(r^2) = K \int_{r_A}^{r_B} \frac{2rdr}{2r^3} = K \int_{r_A}^{r_B} \frac{dr}{r^2} \\ & \quad (\because r = \sqrt{x^2 + y^2}) \end{aligned}$$

$$= K \left[-\frac{1}{r} \right]_{r_A}^{r_B} = K \left[\frac{1}{r_A} - \frac{1}{r_B} \right]$$

Here, $r_A = a$, $r_B = a$

$$\Rightarrow W = 0$$

11. (a)

12. (b): Change in momentum = $\frac{\text{power} \times \text{total time}}{\text{speed of light}}$

$$p_f - p_i = \frac{Pt}{c}$$

Here, $p_i = 0$, $P = 30 \text{ mW} = 30 \times 10^{-3} \text{ W}$

$$c = 3 \times 10^8 \text{ ms}^{-1}, t = 100 \text{ ns} = 100 \times 10^{-9} \text{ s} = 10^{-7} \text{ s}$$

$$\therefore p_f = \frac{(30 \times 10^{-3} \text{ W})(10^{-7} \text{ s})}{3 \times 10^8 \text{ ms}^{-1}} = 1.0 \times 10^{-17} \text{ kg ms}^{-1}$$

13. (5): Velocity of the first

$$\text{bob at A} = \sqrt{5gl_1}$$

Velocity of the first

$$\text{bob at B} = \sqrt{gl_1}$$

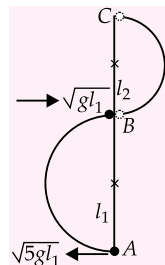
At point B it collides elastically with another bob of same mass m suspended by a string of length l_2 as shown in figure.

When two bodies of equal masses undergoes an elastic collision, their velocities are interchanged.

$$\therefore \text{Velocity of the second bob at B} = \sqrt{gl_1}$$

But to complete the vertical circle, the velocity of the second bob at B = $\sqrt{5gl_2}$

$$\therefore \sqrt{gl_1} = \sqrt{5gl_2} \text{ or } \frac{l_1}{l_2} = 5$$



14. (5): As $P = \frac{W}{t}$

$$\therefore W = Pt = (0.5 \text{ W})(5 \text{ s}) = 2.5 \text{ J}$$

According to work-energy theorem

$$W = K_f - K_i$$

$$W = \frac{1}{2}mv^2 \quad (\because u = 0)$$

$$\therefore \frac{1}{2}mv^2 = 2.5 \text{ or } v^2 = \frac{2 \times 2.5}{m} = \frac{2 \times 2.5}{0.2}$$

$$\text{or } v = 5 \text{ ms}^{-1}$$

15. (4): According to work-energy theorem

$$\frac{1}{2}mV^2 = \mu mgx + \frac{1}{2}kx^2$$

Substituting the given values, we get

$$\frac{1}{2} \times 0.18 \times V^2 = 0.1 \times 0.18 \times 10 \times 0.06 + \frac{1}{2} \times 2 \times (0.06)^2$$

$$9 \times 10^{-2}V^2 = 108 \times 10^{-4} + 36 \times 10^{-4}$$

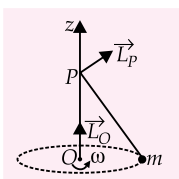
$$V^2 = \frac{144 \times 10^{-4}}{9 \times 10^{-2}} = 16 \times 10^{-2} = \frac{16}{100}$$

$$V = \frac{4}{10} \text{ m/s}$$

$$\therefore N = 4$$

16. (8)

17. (c):



Magnitude and direction of \vec{L}_O remain constant. Magnitude of \vec{L}_P remains constant but direction of \vec{L}_P changes.

18. (b): Let M and l be the mass and length of the rod respectively and m be the mass of the insect. Let the insect be at a distance x from O at any instant of time t .

$$\therefore x = vt$$

...(i)

Angular momentum of the system about O ,

$$L = \left[\frac{Ml^2}{12} + mx^2 \right] \omega$$

$$= \left[\frac{Ml^2}{12} + m(vt)^2 \right] \omega$$

$$= \left[\frac{Ml^2}{12} + mv^2 t^2 \right] \omega$$

$$\text{As } |\vec{\tau}| = \frac{dL}{dt} = \frac{d}{dt} \left[\frac{Ml^2}{12} + mv^2 t^2 \right] \omega$$

As ω and v remain constant

$$\therefore |\vec{\tau}| = 2m\omega v^2 t$$

$$|\vec{\tau}| \propto t$$

Hence, the graph $|\vec{\tau}|$ and t is a straight line passing through the $(0, 0)$. Option (b) represents correct plot.

19. (3): Let M be mass of the whole disc.

Then, the mass of the removed disc

$$= \frac{M}{\pi(2R)^2} \pi R^2 = \frac{M}{4}$$

So, moment of inertia of the remaining disc about an axis passing through O

$$I_O = \frac{1}{2} M(2R)^2 - \left[\frac{1}{2} \left(\frac{M}{4} \right) R^2 + \frac{M}{4} R^2 \right]$$

$$= 2MR^2 - \left[\frac{MR^2 + 2MR^2}{8} \right]$$

$$= 2MR^2 - \frac{3}{8} MR^2 = MR^2 \left[2 - \frac{3}{8} \right] = \frac{13}{8} MR^2$$

Moment of the inertia of the remaining disc about an axis passing through P is

$$I_P = \left[\frac{1}{2} M(2R)^2 + M(2R)^2 \right]$$

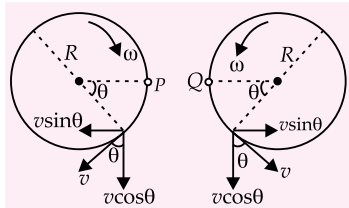
$$- \left[\frac{1}{2} \left(\frac{M}{4} \right) R^2 + \frac{M}{4} (\sqrt{5}R)^2 \right]$$

$$= [2MR^2 + 4MR^2] - \left[\frac{MR^2}{8} + \frac{5MR^2}{4} \right]$$

$$= 6MR^2 - \frac{11}{8} MR^2 = \frac{37}{8} MR^2$$

$$\therefore \frac{I_P}{I_Q} = \frac{37}{8} \times \frac{8}{13} = \frac{37}{13} \approx 3$$

20. (a):



In figure, relative velocity between P and Q
 $v_r = 2v \sin \theta$ or $v_r = 2v \sin(\omega t)$

$$(\because \theta = \omega t)$$

$$\text{At } t = \frac{T}{2}$$

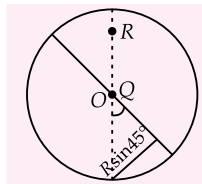
$$v_r = 2v \sin \left(\frac{2\pi}{T} \times \frac{T}{2} \right) = 0 \quad \left(\because \omega = \frac{2\pi}{T} \right)$$

Therefore, only two half cycle will take place.

21. (a): To reach the unshaded portion particle P needs to travel horizontal, range greater than $R \sin 45^\circ$ or $(0.7R)$ but its range is less

than $\frac{R}{2}$. So it will land

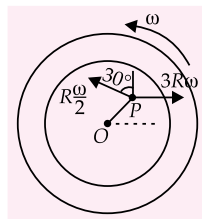
on shaded portion. Q is near to origin, its velocity will be nearly along QR so it will land in unshaded portion.



22. (a)

23. (d)

24. (a,b):



The velocity at centre O is

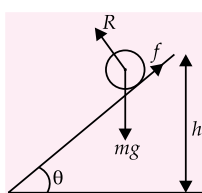
$$v_0 = 3R\omega \hat{i}$$

The velocity at the point P

$$v_P = 3R\omega \hat{i} - \frac{R\omega}{2} \sin 30^\circ \hat{i} + \frac{R\omega}{2} \cos 30^\circ \hat{k}$$

$$v_P = \frac{11}{4} R\omega \hat{i} + \frac{\sqrt{3}}{4} R\omega \hat{k}$$

25. (d):



In figure,

$$mg \sin \theta - f = ma \quad \dots(i)$$

For rotational motion

$$fR = I\alpha \quad \dots(ii)$$

For rolling without slipping

$$\alpha R = a \quad \dots(iii)$$

From (ii) and (iii)

$$f = \frac{Ia}{R^2} \quad \dots(iv)$$

From (iv) and (i)

$$mg \sin \theta - \frac{Ia}{R^2} = ma \Rightarrow a = \frac{mg \sin \theta}{(I/R^2 + m)}$$

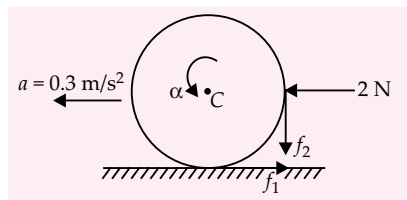
Since $I_P > I_Q$. So, $a_P < a_Q$

Now, $v^2 = u^2 + 2as \Rightarrow v \propto a$

$\therefore (v_Q > v_P)$

Therefore, $\omega_P < \omega_Q$ ($\because v = R\omega$)

26. (4):



As $2 - f_1 = Ma$

$$f_1 = 2 - Ma = 2 - 2 \times 0.3 = 1.4 \text{ N}$$

Taking torque about C

$$f_1 R - f_2 R = I_C \alpha$$

$$(f_1 - f_2)R = MR^2 \frac{a}{R} \quad \left(\because \alpha = \frac{a}{R} \right)$$

$$f_1 - f_2 = Ma$$

$$f_2 = f_1 - Ma = 1.4 - 2 \times 0.3 = 0.8 \text{ N}$$

$$f_2 = 2\mu$$

$$\mu = \frac{0.8}{2} = 0.4 = \frac{4}{10}$$

$$\mu = \frac{P}{10} \quad \text{Hence, } P = 4$$

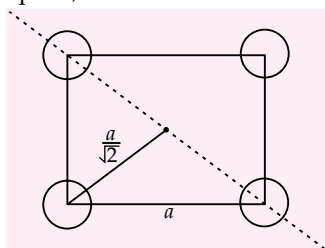
27. (9): Here,

Mass of each sphere, $M = 0.5 \text{ kg}$

Radius of each sphere,

$$R = \frac{\sqrt{5}}{2} \text{ cm} = \frac{\sqrt{5}}{2} \times 10^{-2} \text{ cm}$$

Side of a square, $a = 4 \text{ cm} = 4 \times 10^{-2} \text{ m}$

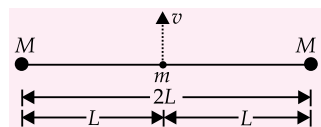


Moment of inertia of the system about the diagonal of the square is

$$\begin{aligned} I &= \frac{2}{5}MR^2 + \left(\frac{2}{5}MR^2 + M\left(\frac{a}{\sqrt{2}}\right)^2 \right) + \\ &\quad \frac{2}{5}MR^2 + \left(\frac{2}{5}MR^2 + M\left(\frac{a}{\sqrt{2}}\right)^2 \right) \\ &= \frac{8}{5}MR^2 + Ma^2 \\ &= \left[\frac{8}{5} \times 0.5 \times \left(\frac{\sqrt{5}}{2} \right)^2 + 0.5 \times 4^2 \right] \times 10^{-4} \\ &= [1 + 8] \times 10^{-4} \text{ kg m}^2 \\ &= 9 \times 10^{-4} \text{ kg m}^2 \\ I &= N \times 10^{-4} \text{ kg m}^2 \\ \therefore N &= 9 \end{aligned}$$

28. (a,c)

29. (b,d): The situation is as shown in the figure



Applying the conservation of mechanical energy, we get

$$\begin{aligned} -\frac{GMm}{L} - \frac{GMm}{L} + \frac{1}{2}mv^2 &= 0 + 0 \\ \frac{1}{2}mv^2 &= \frac{2GMm}{L} \Rightarrow v = \sqrt{\frac{4GM}{L}} = 2\sqrt{\frac{GM}{L}} \end{aligned}$$

30. (b,d): The escape velocity for the surface of earth is

$$\begin{aligned} V_e &= \sqrt{\frac{2GM}{R}} \\ &= \sqrt{\frac{2 \cdot G \rho \frac{4}{3}\pi R^3}{R}} \end{aligned}$$

(Since ρ is same for all planet) $\dots(i)$

$$V_e \propto R$$

Surface area of P, $4\pi R_P^2 = A$

Surface area of Q, $4\pi R_Q^2 = 4A$

$$\therefore \frac{R_P}{R_Q} = \frac{1}{2} \Rightarrow R_Q = 2R_P \quad \dots(ii)$$

The spherical planet R has mass

$$M_R = M_P + M_Q$$

$$\frac{4}{3}\rho\pi R_R^3 = \frac{4}{3}\rho\pi R_P^3 + \frac{4}{3}\rho\pi R_Q^3 \Rightarrow R_R^3 = R_P^3 + R_Q^3$$

$$\text{or } R_R^3 = R_P^3 + (2R_P)^3 \quad \text{Using (ii)}$$

So, $R_R = (9)^{1/3}R_P$

Therefore, $R_R > R_Q > R_P$

From equation (i),

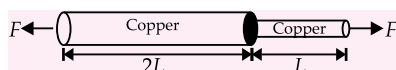
$$V_R > V_Q > V_P$$

and from equation (ii)

$$\frac{V_P}{V_Q} = \frac{1}{2}$$

31. (b): Escape speed, $v_e = \sqrt{2} \times \text{orbital speed} = \sqrt{2}V$
 \therefore Kinetic energy of the object
 $= \frac{1}{2}mv_e^2 = \frac{1}{2}m(\sqrt{2}V)^2 = mV^2$

32. (c): The situation is as shown in figure.



By definition of Young's modulus

$$\Delta L = \frac{FL}{YA}$$

\therefore For thick wire

$$\Delta L_1 = \frac{F(2L)}{Y\pi(2R)^2} \quad \dots(i)$$

For thin wire

$$\Delta L_2 = \frac{FL}{Y\pi R^2} \quad \dots(ii)$$

Divide (ii) by (i), we get

$$\frac{\Delta L_2}{\Delta L_1} = \frac{FL}{Y\pi R^2} \times \frac{Y\pi(2R)^2}{F(2L)} = 2$$

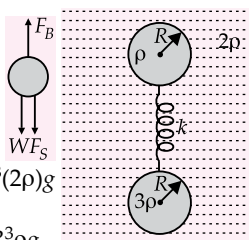
33. (a,d): The situation is as shown in adjacent figure. At equilibrium, for upper sphere

$$W + F_S = F_B$$

$$\frac{4}{3}\pi R^3 \rho g + kx = \frac{4}{3}\pi R^3 (2\rho)g$$

$$kx = \frac{4}{3}\pi R^3 2\rho g - \frac{4}{3}\pi R^3 \rho g$$

$$kx = \frac{4\pi R^3 \rho g}{3} \text{ or } x = \frac{4\pi R^3 \rho g}{3k}$$



34. (d)

35. (a,b,d): Let V be the volume of each sphere and T is the tension in the string.

For the string to be taut,

$$d_F Vg > d_A Vg$$

$$\Rightarrow d_F > d_A$$

$$\text{and } d_B Vg > d_F Vg$$

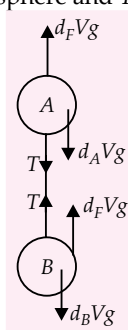
$$\Rightarrow d_B > d_F$$

For an equilibrium

$$d_F Vg + d_F Vg + T = T + d_A Vg + d_B Vg$$

$$\text{or } d_A + d_B = 2d_F$$

36. (a)



37. (b,c,d): (a) In 0-100 K,

C increases with T but not linearly. So R increases but not linearly.

- (b) As $\Delta Q = mC\Delta T$

$$Q = m \int C \Delta T = m \text{ area under } C-T \text{ curve}$$

From the graph it is clear that area under $C-T$ is more in 400-500 K than in 0-100 K.

Therefore, heat absorbed in 0-100 K is less than in 400-500 K.

- (c) In 400-500 K,

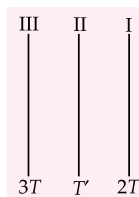
C remains constant so there is no change in R .

- (d) In 200-300 K,

C increases so R increases.

38. (c): Let T' be the temperature of the middle plate and A be area of each plate.

Under steady state, the rate of energy received by the middle plate is equal to rate of energy emitted by it.



$$\therefore \sigma A(3T)^4 - \sigma A(T')^4 = \sigma A(T')^4 - \sigma A(2T)^4$$

$$\sigma A[(3T)^4 - (T')^4] = \sigma A[(T')^4 - (2T)^4]$$

$$(3T)^4 - (T')^4 = (T')^4 - (2T)^4$$

$$2(T')^4 = (3T)^4 + (2T)^4$$

$$= T^4(3^4 + 2^4) = T^4(81 + 16) = 97T^4$$

$$T'^4 = \frac{97}{2}T^4 \text{ or } T' = \left(\frac{97}{2}\right)^{1/4} T$$

39. (a,c,d)

40. (3): Young's modulus, $Y = \frac{FL}{A\Delta L}$

where the symbols have their usual meaning

$$Y = \frac{mgL}{(\pi R^2)\Delta L} \quad \dots(i)$$

$$\therefore \Delta L = \alpha L \Delta T \text{ or } \frac{\Delta L}{L} = \alpha \Delta T$$

Substituting this value in equation (i), we get

$$Y = \frac{mg}{\pi R^2 \alpha \Delta T} \text{ or } m = \frac{\pi R^2 Y \alpha \Delta T}{g}$$

Substituting the given values, we get

$$m = \frac{\pi \times (1 \times 10^{-3})^2 \times 10^{11} \times 10^{-5} \times 10}{10}$$

$$= \pi \text{ kg} \approx 3 \text{ kg}$$

41. (d): According to 1st law of thermodynamics,

$$\Delta Q = \Delta U + \Delta W = nC_V \Delta T + nR \Delta T$$

$$= n \left(\frac{f}{2} R \right) \Delta T + nR \Delta T \left(\because C_V = \frac{f}{2} R \right)$$

$$= nR \Delta T \left(\frac{f}{2} + 1 \right)$$

Here, $n = 2$, $R = 8.31 \text{ J/mol K}$,

$$\Delta T = 35^\circ\text{C} - 30^\circ\text{C} = 5^\circ\text{C} \text{ and } f = 3$$

$$\therefore \Delta Q = 2 \times 8.31 \times 5 \left(\frac{3}{2} + 1 \right) = 207.75 \approx 208 \text{ J}$$

42. (a): Helium is a monoatomic gas.

For monoatomic gas, $\gamma = \frac{5}{3}$

For an adiabatic process,

$TV^{\gamma-1} = \text{constant}$

$$\Rightarrow T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$T_2 = T_1 \left(\frac{V_1}{V_2} \right)^{\gamma-1}$$

Substituting the given values, we get

$$T_2 = T_1 \left(\frac{5.6}{0.7} \right)^{\left(\frac{5}{3} - 1 \right)} = T_1 (8)^{2/3} = 4T_1$$

Number of moles of He,

$$n = \frac{5.6 \text{ litre}}{22.4 \text{ litre}} = \frac{1}{4}$$

Work done during an adiabatic process is

$$W = \frac{nR[T_1 - T_2]}{(\gamma - 1)} = \frac{\frac{1}{4}R[T_1 - 4T_1]}{\left[\frac{5}{3} - 1 \right]} = -\frac{9}{8}RT_1$$

Negative sign shows that work is done on the gas.

43. (d) 44. (a) 45. (d)

46. $A \rightarrow p, r, t$; $B \rightarrow p, r$; $C \rightarrow q, s$; $D \rightarrow r, t$

47. (a, d)

48. (a, d): Restoring torque is same for both the cases. Hence (a) is correct.

$$\text{In case A, } I_A = \frac{mL^2}{3} + \frac{MR^2}{2} + ML^2$$

$$\text{In case B, } I_B = \frac{mL^2}{3} + ML^2$$

As $I_A > I_B$ and $\tau_A = \tau_B$

$$\Rightarrow \omega_A < \omega_B$$

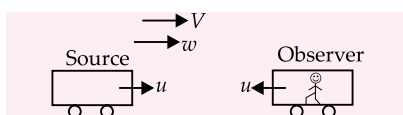
Hence, (d) is correct.

49. (a): The frequency will be same.

As $v_0 = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$ does not depend on the constant external force. But due to constant external force, the mean position gets shifted. So option (a) is correct.

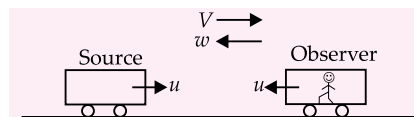
50. (b, c)

51. (a, b):



If the wind blows from the source to the observer, the frequency heard by the observer is

$$f_2 = \left(\frac{(V+w)+u}{(V+w)-u} \right) f_1 \Rightarrow f_2 > f_1$$



If the wind blows from the observer to the source, the frequency heard by the observer is

$$f_2 = \left(\frac{(V-w)+u}{(V-w)-u} \right) f_1 \Rightarrow f_2 > f_1$$

52. (b, d): At open end phase of pressure wave change by π , so high pressure pulse gets reflected as a low pressure pulse. While at closed end phase of pressure wave does not change, so high pressure pulse gets reflected again as a high pressure pulse.

53. (b): First resonance, $\frac{\lambda}{4} = (l_1 + 0.6r)$

$$\text{Also, } \frac{v}{4v} = (l_1 + 0.6r) \quad (\because \lambda = \frac{v}{v})$$

Here, r is internal radius of resonance column and l_1 is the length of water level in column

Given, $v = 336 \text{ m/s}$, $v = 512 \text{ Hz}$ and $r = \frac{4}{2} \text{ cm}$

$$\therefore l_1 = \frac{336 \times 10^2}{4 \times 512} - (0.6) \times \frac{4}{2}$$

$$l_1 = 15.2 \text{ cm}$$

54. (a): Here,

Speed of sound in air, $v = 320 \text{ m/s}$

Frequency of source, $v = 8 \text{ kHz} = 8 \times 10^3 \text{ Hz}$

Velocity of the police car (source),

$$v_s = 36 \text{ km/hr} = 36 \times \frac{5}{18} \text{ m/s} = 10 \text{ m/s}$$

As the police car (source) is moving towards a tall building, the frequency of sound received by the building is

$$v' = v \left[\frac{v}{v - v_s} \right] \quad \dots (i)$$

For the reflected sound, building acts as source and the driver himself is the listener which is moving towards the building. Hence, the frequency heard by the driver is

$$v'' = v' \left[\frac{v + v_L}{v} \right] = v \left[\frac{v + v_L}{v - v_s} \right] \quad (\text{Using (i)})$$

$$= v \left[\frac{v + v_s}{v - v_s} \right] \quad [\text{As } v_L = v_s]$$

$$v'' = 8 \times 10^3 \left[\frac{320 + 10}{320 - 10} \right] = 8 \times 10^3 \times \frac{330}{310}$$

$$= 8.51 \times 10^3 \text{ Hz} \approx 8.5 \text{ kHz}$$

55. (b)

56. $A \rightarrow p, t$; $B \rightarrow p, s$; $C \rightarrow q, s$; $D \rightarrow q, r$

Thought Provoking

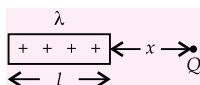
Electrostatics



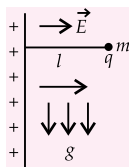
Problems

By : Prof. Rajinder Singh Randhawa*

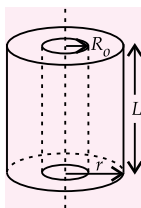
1. Find the force of interaction between the point charge 'Q' and a thin conductor of linear charge density $\frac{dq}{dl} = \lambda$ as shown in figure.



2. A small bob of a mass 'm' and charge q is released from the given position. It swings in a vertical plane by the effect of gravity and electric field due to a large uniform charged sheet of surface charge density σ. Find the maximum angle that the bob swings before coming to rest momentarily.



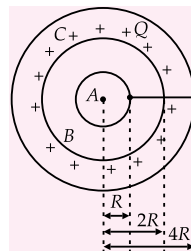
3. A straight infinitely long cylinder of radius R_0 is uniformly charged with charge density σ_0 . The cylinder serves as a source of electrons, with the velocity vectors of emitted electrons perpendicular to its surface.



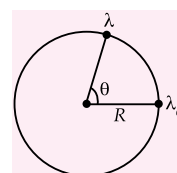
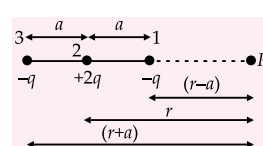
What must be the electron velocity to ensure that the electron can move away from the axis of the cylinder to a distance greater than r.

4. Figure shows three conducting and concentric spheres A, B and C with radii R, 2R and 4R respectively. A and C are connected by a

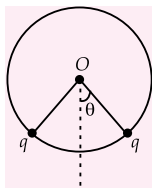
conducting wire and B is uniformly charged (charge = +Q). Find (a) charges on conductors A and C. (b) Potentials of A and B.



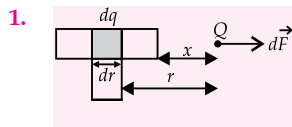
5. Three charges $-q$, $+2q$ and $-q$ are arranged on a line as shown in figure. Calculate the electric field at a distance $r > a$ on the line.
6. Consider Earth to be a ball of radius R and mass M. Let the charge of Earth be Q. (a) What must be the maximum mass 'm' of an object carrying an electric charge equal to that of a proton and moving in the electric field of the Earth so that the object may escape Earth's gravitational pull and fly off into outer space? (b) What can be maximum charge, Q_{\max} carried by a dust particle (an object) and how can such a charge be imparted to the object?
7. A thin non-conducting ring of radius R has a linear charge density $\lambda = \lambda_0 \cos \theta$, where λ_0 is the value of λ at $\theta = 0^\circ$. Find the net electric dipole moment for this charge distribution.



8. Two identical beads of mass ' m ' and charge ' q ' are shown in figure. The beads can slide smoothly on a wire frame kept in a vertical frame. Determine angular position ' θ ' w.r.t. vertical diameter. Now the beads are given a small angular displacement. Show that they perform simple harmonic motion.



SOLUTIONS



Consider an elementary charge dq at a distance ' r ' from Q . The force dF acting on Q due to dq is

$$dF = \frac{Qdq}{4\pi\epsilon_0 r^2}$$

The net force on Q is $F = \int dF$

$$F = \frac{Q}{4\pi\epsilon_0} \int \frac{dq}{r^2} = \frac{Q}{4\pi\epsilon_0} \int_x^{x+l} \frac{\lambda dr}{r^2} \quad [\because dq = \lambda dr]$$

$$\Rightarrow F = \frac{Q\lambda}{4\pi\epsilon_0} \left[\frac{1}{x} - \frac{1}{x+l} \right] \Rightarrow F = \frac{Q\lambda}{4\pi\epsilon_0 x(l+x)}$$

2. Since $W_{\text{net}} = W_{\text{gr}} + W_{\text{es}}$

$$\Rightarrow 0 = mgy - qEx$$

$$\Rightarrow \frac{y}{x} = \frac{qE}{mg} \quad \dots(i)$$

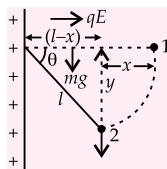
From figure, $\sin\theta = \frac{y}{l}$

$$\Rightarrow y = l \sin\theta$$

$$\text{and } \cos\theta = \frac{l-x}{l} \Rightarrow \cos\theta = 1 - \frac{x}{l} \text{ or } x = l(1 - \cos\theta)$$

$$\therefore \frac{y}{x} = \frac{l \sin\theta}{l(1 - \cos\theta)} = \frac{2 \sin\theta / 2}{2 \cos^2\theta / 2} = \frac{1}{\tan\theta / 2}$$

$$\tan \frac{\theta}{2} = \frac{x}{y} = \frac{mg}{qE}$$



Solution Senders of Physics Musing

SET-7

- Divyesh Srivastava (Lucknow)
- Namit Bhasin (Ludhiana)

SET-8

- Vikash Rawani (Dhanbad)
- Arun Sharma (Bhopal)
- Neha Gupta (New Delhi)

$$\text{Now, } E = \frac{\sigma}{\epsilon_0}$$

$$\therefore \tan \frac{\theta}{2} = \frac{mg\epsilon_0}{q\sigma} \Rightarrow \theta = 2 \tan^{-1} \left(\frac{\epsilon_0 mg}{q\sigma} \right)$$

3. Consider a coaxial cylinder as a Gaussian surface, then

$$\epsilon_0 (2\pi r L) E = (2\pi R_0 L) \sigma \text{ or } E = \frac{\sigma R_0}{\epsilon_0 r} \quad \dots (i)$$

If we apply Newton's second law,

$$m_e \frac{d^2 r}{dt^2} = -e \frac{R_0 \sigma}{\epsilon_0 r} \quad \dots (ii)$$

Also, using law of conservation of energy, we get

$$\frac{1}{2} m_e v_o^2 - eV_o = -eV \quad \dots (iii)$$

where V_o is the potential of cylinder and V is the potential at a distance r from the axis of the cylinder.

$$\text{Since, } E = -\frac{dV}{dr}$$

Using equation (i), we get

$$\frac{R_0 \sigma}{\epsilon_0 r} = -\frac{dV}{dr} \Rightarrow dV = -\frac{R_0 \sigma}{\epsilon_0} \frac{dr}{r}$$

On integration, we get

$$V = -\frac{R_0 \sigma}{\epsilon_0} \ln r + C \quad \dots (iv)$$

$$\text{Also, } V_o = -\frac{R_0 \sigma}{\epsilon_0} \ln R_0 + C \quad \dots (v)$$

Using equations (iv) and (v), in equation (iii), we get

$$v_o = \sqrt{\frac{2eR_0 \sigma \ln(r/R_0)}{\epsilon_0 m_e}}$$

4. (a) Let the charges on A and C be q_1 and q_2 respectively.

From conservation of charge, $q_1 + q_2 = 0$.

Hence, $q_1 = -q_2$

Since A and C are connected by a conducting wire, so they have same potential,

$$V_A = \frac{q_1}{4\pi\epsilon_0 R} + \frac{Q}{4\pi\epsilon_0 2R} + \frac{q_2}{4\pi\epsilon_0 4R} \text{ and}$$

$$V_C = \frac{q_1}{4\pi\epsilon_0 4R} + \frac{Q}{4\pi\epsilon_0 4R} + \frac{q_2}{4\pi\epsilon_0 R}$$

Since $V_A = V_C$, we get

Solving, $4q_1 + 2Q = q_1 + Q$

$$\text{Hence, } q_1 = -\frac{Q}{3} \text{ and } q_2 = \frac{Q}{3}$$

$$(b) V_A = \frac{1}{4\pi\epsilon_0 R} \left[-\frac{Q}{3} + \frac{Q}{2} + \frac{Q}{12} \right] = \frac{Q}{16\pi\epsilon_0 R}$$

$$\text{and } V_B = \frac{1}{8\pi\epsilon_0 R} \left[-\frac{Q}{3} + Q + \frac{Q}{6} \right] = \frac{5Q}{48\pi\epsilon_0 R}$$

5. The net field is $|\vec{E}| = |\vec{E}_1| + |\vec{E}_2| + |\vec{E}_3|$

$$|\vec{E}| = \left| \frac{-q}{4\pi\epsilon_0(r-a)^2} + \frac{2q}{4\pi\epsilon_0 r^2} - \frac{q}{4\pi\epsilon_0(r+a)^2} \right|$$

$$= \frac{q}{4\pi\epsilon_0} \left[\frac{-1}{(r-a)^2} + \frac{2}{r^2} - \frac{1}{(r+a)^2} \right]$$

$$|\vec{E}| = \frac{q}{4\pi\epsilon_0 r^2} \left[\left\{ 1 - \left(\frac{a}{r} \right)^2 \right\}^{-2} + 2 - \left\{ 1 + \left(\frac{a}{r} \right)^2 \right\}^{-2} \right]$$

If $r > a$, we can use binomial expansion theorem

$$(1+x)^n = 1 + nx + \frac{n(n-1)}{2!}x^2 \text{ for } |x| \ll 1.$$

$$|\vec{E}| = \frac{q}{4\pi\epsilon_0 r^2} \left[\left\{ 1 - \left(\frac{2a}{r} + \frac{3a^2}{r^2} \right) \right\} + 2 - \left\{ 1 - \frac{2a}{r} + \frac{3a^2}{r^2} \right\} \right]$$

$$= \frac{q}{4\pi\epsilon_0 r^2} \left[-1 - \frac{2a}{r} - \frac{3a^2}{r^2} + 2 - 1 + \frac{2a}{r} - \frac{3a^2}{r^2} \right]$$

$$= \frac{q}{4\pi\epsilon_0 r^2} \cdot \frac{-6a^2}{r^2} = \frac{6qa^2}{4\pi\epsilon_0 r^4}$$

6. (a) Let the object be launched from the Earth's surface with initial velocity $v_0 = 0$, then from law of conservation of energy,

$$\frac{-GMm}{R} + \frac{QQ_p}{4\pi\epsilon_0 R} = 0 \text{ or } m = \frac{QQ_p}{4\pi\epsilon_0 GM} \dots (i)$$

(b) Now we consider the dust particle as a small metal ball of radius r that acquires its charge from Earth, with which it is in direct contact, charge will flow until they become of same potential and charge flow stops, then

$$V = \frac{Q_{\max}}{4\pi\epsilon_0 r} = \frac{Q}{4\pi\epsilon_0 R} \text{ or } Q_{\max} = \frac{Qr}{R} \dots (ii)$$

Let ρ be the density of the metal ball, then its mass,

$$m = \frac{4}{3}\pi r^3 \rho \dots (iii)$$

Putting equations (ii) and (iii) in equation (i), we get

$$-\frac{GM(4/3)\pi r^3 \rho}{R} + \frac{QrQ}{4\pi\epsilon_0 R^2} = 0$$

On solving, we get

$$r = \frac{Q}{4\pi\sqrt{\epsilon_0 GMR\rho}}$$

Putting r in equation (ii), we get

$$Q_{\max} = \frac{Q^2}{4\pi R} \sqrt{\frac{3}{\epsilon_0 GMR\rho}}$$

7. Consider two differential elements A and B as shown in figure.

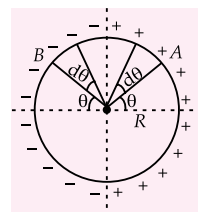
$$\text{Dipole moment of the pair,}$$

$$= [\lambda_0 \cdot \cos\theta] R d\theta \times 2R \cos\theta$$

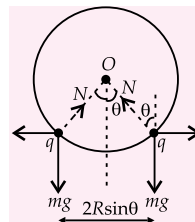
$$= 2\lambda_0 R^2 \cos^2\theta d\theta$$

\therefore Dipole moment of the charge distribution

$$= 2\lambda_0 R^2 \int_{-\pi/2}^{\pi/2} \cos^2\theta d\theta = \pi R^2 \lambda_0$$



- 8.



$$\text{In equilibrium, } N \sin\theta = F = \frac{q^2}{4\pi\epsilon_0 (2R \sin\theta)^2} \dots (i)$$

$$\text{and } N \cos\theta = mg \dots (ii)$$

Dividing equation (i) by (ii), we get

$$\tan\theta = \frac{q^2}{4\pi\epsilon_0 mg (2R \sin\theta)^2} \dots (iii)$$

After small angular displacement, we consider F is constant.

In equilibrium, the net torque about centre of circle becomes zero.

$$\therefore -mg \cdot R \sin\theta + F \cdot R \cos\theta = 0 \dots (iv)$$

After a small angular displacement $d\theta$ of right bead,

$$-mgR \sin(\theta + d\theta) + FR \cos(\theta + d\theta) = mR^2 \alpha \dots (v)$$

$$-mgR [\sin\theta \cos d\theta + \cos\theta \sin d\theta] + FR [\cos\theta \cos d\theta - \sin\theta \sin d\theta] = mR^2 \alpha \dots (vi)$$

For small θ , $\sin\theta \approx \theta$ and $\cos\theta \approx 1$, equation (vi) becomes

$$-mgR [\sin\theta + \cos\theta d\theta] + FR [\cos\theta - \sin\theta d\theta] = mR^2 \alpha \dots (vii)$$

From equation (iv) and (vii), we have

$$-[mgR \cos\theta + FR \sin\theta] d\theta = mR^2 \alpha$$

$$\text{or } \alpha = - \left[\frac{mgR \cos\theta + FR \sin\theta}{mR^2} \right] d\theta \dots (viii)$$

Compare it with equation of S.H.M.,

$$\alpha = -\omega^2 d\theta \dots (ix)$$

$$\omega = \sqrt{\frac{mgR \cos\theta + \frac{q^2 R}{4\pi\epsilon_0 (2R \sin\theta)^2} \sin\theta}{mR^2}}$$

$$\omega = \sqrt{\frac{8\pi\epsilon_0 R^2 mg \sin 2\theta + q^2}{16\pi\epsilon_0 mR^3 \sin\theta}}$$

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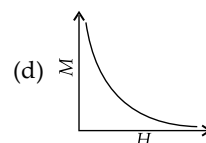
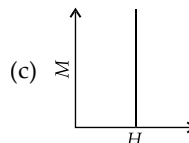
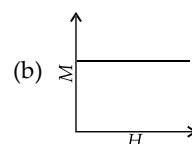
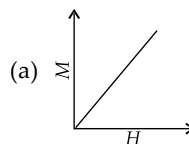
NCERT Xtract

New

Questions for Medical/ Engineering Entrance Exams

Magnetism and Matter

- Magnetic moment for a solenoid and corresponding bar magnet is
 - equal for both
 - more for solenoid
 - more for bar magnet
 - none of these
- A magnetic needle has magnetic moment $5.8 \times 10^{-2} \text{ A m}^2$ and moment of inertia of $7.8 \times 10^{-6} \text{ kg m}^2$, it performs 12 complete oscillations in 6.0 s. What is the magnitude of magnetic field?
 - 0.011 T
 - 0.021 T
 - 0.031 T
 - 0.041 T
- The torque and magnetic potential energy of a magnetic dipole in most stable position in a uniform magnetic field (\vec{B}) having magnetic moment (\vec{m}) will be
 - $-mB$, zero
 - mB , zero
 - zero, mB
 - zero, $-mB$
- A solenoid of cross-sectional area $2 \times 10^{-4} \text{ m}^2$ and 900 turns has 0.6 A m^2 magnetic moment. Then the current flowing through it is
 - 2.24 A
 - 2.34 m A
 - 3.33 A
 - 3.33 m A
- What is the magnitude of axial field due to a bar magnet of length 3 cm at a distance of 75 cm from its mid-point if its magnetic moment is 0.6 A m^2 ?
 - $0.013 \mu\text{T}$
 - $0.113 \mu\text{T}$
 - $0.284 \mu\text{T}$
 - $0.313 \mu\text{T}$
- The correct M - H curve for a paramagnetic material at a constant temperature (T) is represented by



- Superconductors are
 - most exotic diamagnetic materials
 - ferromagnetic material with low resistivity
 - Paramagnetic materials at high temperature
 - none of these
- A closely wound solenoid of 750 turns and area of cross section $5 \times 10^{-4} \text{ m}^2$ carries a current of 3.0 A. Its associated magnetic moment is
 - 4.12 J T^{-1}
 - 3.12 J T^{-1}
 - 2.12 J T^{-1}
 - 1.13 J T^{-1}
- A circular coil of 25 turns and radius of 12 cm is placed in a uniform magnetic field of 0.5 T normal to the plane of coil. If the current in the coil is 5 A, then total torque experienced by the coil is
 - 1.5 N m
 - 2.5 N m
 - 3.5 N m
 - zero
- If a magnetic material is having magnetic susceptibility (χ) = -1, then the relative magnetic permeability (μ_r) and type of magnetic material are respectively
 - 0, diamagnetic
 - 2, ferromagnetic
 - 1, paramagnetic
 - 1, diamagnetic

11. Two identical magnetic dipoles of magnetic moment 2 A m^2 are placed at a separation of 2 m with their axes perpendicular to each other in air. The resultant magnetic field at a midpoint between the dipoles is
 (a) $4\sqrt{5} \times 10^{-5} \text{ T}$ (b) $2\sqrt{5} \times 10^{-5} \text{ T}$
 (c) $4\sqrt{5} \times 10^{-7} \text{ T}$ (d) $2\sqrt{5} \times 10^{-7} \text{ T}$
12. A short bar magnet has a magnetic moment of 0.48 J T^{-1} . The magnitude and direction of magnetic field produced by the magnet at a distance of 10 cm from the centre of the magnet on its axis is
 (a) 0.48×10^{-4} along N-S direction
 (b) $0.28 \times 10^{-4} \text{ T}$ along S-N direction
 (c) $0.28 \times 10^{-4} \text{ T}$ along N-S direction
 (d) $0.96 \times 10^{-4} \text{ T}$ along S-N direction
13. A short bar magnet has a magnetic moment of 0.39 J T^{-1} . The magnitude and direction of the magnetic field produced by the magnet at a distance of 20 cm from the centre of the magnet on the equatorial line of the magnet is
 (a) 0.049 G , N-S direction
 (b) 4.95 G , S-N direction
 (c) 0.0195 G , S-N direction
 (d) 19.5 G , N-S direction
14. At a certain location in Africa, compass points 12° west of geographic north. The north tip of magnetic needle of a dip circle placed in the plane of magnetic meridian points 60° above the horizontal. The horizontal component of earth's field is measured to be 0.16 G . The magnitude of earth's field at the location is
 (a) 0.32 G (b) 0.42 G
 (c) 4.2 G (d) 3.2 G
15. A paramagnetic sample shows a net magnetisation of 10 A m^{-1} when placed in an external magnetic field of 0.8 T at a temperature of 4 K . When the same sample is placed in an external magnetic field of 0.3 T at a temperature of 16 K , the magnetisation will be
 (a) $\frac{32}{3} \text{ A m}^{-1}$ (b) $\frac{2}{3} \text{ A m}^{-1}$
 (c) $\frac{15}{16} \text{ A m}^{-1}$ (d) 8 A m^{-1}
16. The magnetic induction at a point 1 \AA away from a proton measured along its axis of spin is (Take magnetic moment of the proton as $1.4 \times 10^{-26} \text{ A m}^2$).
 (a) 0.28 mT (b) 28 mT
 (c) 0.028 mT (d) 2.8 mT
17. A permanent magnet in the shape of a thin cylinder of length 50 cm has intensity of magnetisation 10^6 A m^{-1} . The magnetisation current is
 (a) $5 \times 10^5 \text{ A}$ (b) $6 \times 10^5 \text{ A}$
 (c) $5 \times 10^4 \text{ A}$ (d) $6 \times 10^4 \text{ A}$
18. Core of electromagnets are made of ferromagnetic materials which have
 (a) low permeability and low retentivity
 (b) high permeability and high retentivity
 (c) high permeability and low retentivity
 (d) low permeability and high retentivity.
19. A domain in ferromagnetic iron is in the form of a cube of side length $2 \text{ }\mu\text{m}$ then the number of iron atoms in the domain are (Molecular mass of iron = 55 g mol^{-1} and density = 7.92 g cm^{-3})
 (a) 6.92×10^{12} atoms (b) 6.92×10^{11} atoms
 (c) 6.92×10^{10} atoms (d) 6.92×10^{13} atoms
20. The magnetic susceptibility of a paramagnetic material at -73°C is 0.0075 , its value at -173°C will be
 (a) 0.0045 (b) 0.0030 (c) 0.0150 (d) 0.0075
21. Point out the correct set of diamagnetic substances
 (a) aluminium, sodium, calcium and oxygen
 (b) bismuth, copper, lead and silicon
 (c) cobalt, nickel, gadolinium and aluminium
 (d) silver, niobium, magnesium and calcium
22. A domain in ferromagnetic iron in the form of cube is having 5×10^{10} atoms. If the side length of this domain is $1.5 \text{ }\mu\text{m}$ and each atom has a dipole moment of $8 \times 10^{-24} \text{ A m}^2$, then magnetisation of domain is
 (a) $11.8 \times 10^5 \text{ A m}^{-1}$ (b) $1.18 \times 10^4 \text{ A m}^{-1}$
 (c) $11.8 \times 10^4 \text{ A m}^{-1}$ (d) $1.18 \times 10^5 \text{ A m}^{-1}$
23. The magnetic field of Earth can be modelled by that of a point dipole placed at the centre of the Earth. The dipole axis makes an angle of 11.3° with the axis of Earth. At Mumbai, declination is nearly zero. Then,
 (a) the declination varies between 11.3° W to 11.3° E .
 (b) the least declination is 0° .
 (c) the plane defined by dipole axis and Earth axis passes through Greenwich.
 (d) declination averaged over Earth must be always negative.
24. A magnetising field of 1500 A m^{-1} produces flux of 2.4×10^{-5} weber in a iron bar of the cross-sectional area of 0.5 cm^2 . The permeability of the iron bar is
 (a) 245 (b) 250 (c) 252 (d) 255

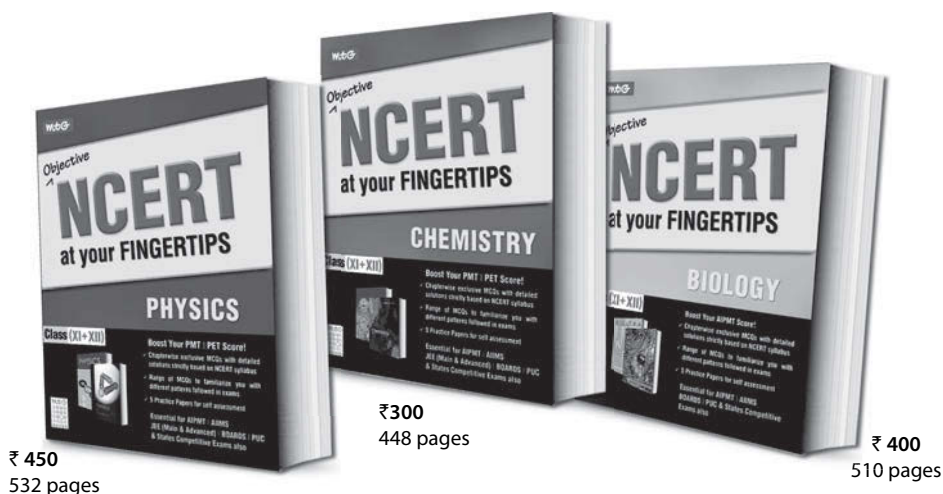
25. A circular coil of 100 turns, radius 10 cm carries a current of 5 A. It is suspended vertically in a uniform horizontal magnetic field of 0.5 T and the field lines make an angle of 60° with the plane of the coil. The magnitude of the torque that must be applied on it to prevent it from turning is
 (a) 2.93 N m (b) 3.43 N m
 (c) 3.93 N m (d) 4.93 N m
26. A long solenoid has 1000 turns per metre and carries a current of 1 A. It has a soft iron core of $\mu_r = 1000$. The core is heated beyond the Curie temperature T_c .
 (a) The \vec{H} field in the solenoid is (nearly) unchanged but \vec{B} field decreases drastically.
 (b) The \vec{H} and \vec{B} fields in the solenoid are nearly unchanged.
 (c) The magnetisation in the core reverses direction.
 (d) The \vec{H} field in the solenoid decreases but \vec{B} field increases drastically.
27. There are two current carrying planar coils made each from identical wires of length L . C_1 , is circular (radius R) and C_2 is square (side a). They are so constructed that they have same frequencies of oscillation when they are placed in the same uniform magnetic field B and carry the same current I . The relation between a and R is
 (a) $a = 2R$ (b) $a = 3R$
 (c) $3a = R$ (d) $a = 4R$
28. Assume the dipole model for earth's magnetic field B which is given by the vertical component of magnetic field, $B_V = \frac{\mu_0}{4\pi} \frac{2m \cos \theta}{r^3}$ and the horizontal component of magnetic field $B_H = \frac{\mu_0}{4\pi} \frac{m \sin \theta}{r^3}$, where $\theta = 90^\circ$ (latitude as measured from magnetic equator), then the loci of point for which dip angle is $\pm 45^\circ$.
 (a) $\tan^{-1}(3)$ (b) $\tan^{-1}(2)$
 (c) $\tan^{-1}(0.5)$ (d) $\tan^{-1}(1)$
29. A dipole of magnetic moment $\vec{m} = 30\hat{j}$ A m² is placed along the y -axis in a uniform magnetic field $\vec{B} = (2\hat{i} + 5\hat{j})$ T. The torque acting on it is
 (a) $-40\hat{k}$ N m (b) $-50\hat{k}$ N m
 (c) $-60\hat{k}$ N m (d) $-70\hat{k}$ N m
30. At a given place on earth's surface the horizontal component of earth's magnetic field is 2×10^{-5} T and resultant magnetic field is 4×10^{-5} T. The angle of dip at this place is
 (a) 30° (b) 60°
 (c) 90° (d) 45°
31. A closely wound solenoid of 3000 turns and area of cross section 2×10^{-4} m², carrying a current of 6 A is suspended through its centre allowing it to turn in a horizontal plane. The magnetic moment associated with the solenoid is
 (a) 1.2 J T^{-1} (b) 2.4 J T^{-1}
 (c) 3.0 J T^{-1} (d) 3.6 J T^{-1}
32. A circular coil of magnetic moment 0.355 J T^{-1} rests with its plane normal to an external field of magnitude 5.0×10^{-2} T. The coil is free to turn about an axis in its plane perpendicular to the field direction. When the coil is turned slightly and released, it oscillates about its stable equilibrium with a frequency of 2 Hz. The moment of inertia of the coil about its axis of rotation is
 (a) $1.13 \times 10^{-1} \text{ kg m}^2$ (b) $1.13 \times 10^{-2} \text{ kg m}^2$
 (c) $1.13 \times 10^{-3} \text{ kg m}^2$ (d) $1.13 \times 10^{-4} \text{ kg m}^2$
33. A magnetic dipole is under the influence of two magnetic fields. The angle between the field directions is 60° and one of the fields has a magnitude of 1.2×10^{-2} T. If the dipole comes to stable equilibrium at an angle of 30° with this field, then the magnitude of the field is
 (a) 1.2×10^{-4} T (b) 2.4×10^{-2} T
 (c) 1.2×10^{-2} T (d) 2.4×10^{-2} T
34. A ring of mean radius 15 cm has 3500 turns of wire wound on a ferromagnetic core of relative permeability 800. The magnetic field in the core for a magnetising current of 1.2 A is
 (a) 2.48 T (b) 3.48 T
 (c) 4.48 T (d) 5.48 T
35. A solenoid has core of a material with relative permeability 500 and its windings carry a current of 1 A. The number of turns of the solenoid is 500 per metre. The magnetization of the material is nearly
 (a) $2.5 \times 10^3 \text{ A m}^{-1}$ (b) $2.5 \times 10^5 \text{ A m}^{-1}$
 (c) $2.0 \times 10^3 \text{ A m}^{-1}$ (d) $2.0 \times 10^5 \text{ A m}^{-1}$

SOLUTION

1. (a): Since a bar magnet and a corresponding solenoid produce similar magnetic fields. Hence the magnetic moment of a bar magnet is equal to the magnetic moment of an equivalent solenoid that produces the same magnetic field.
2. (b): Here, time period of oscillations

$$T = \frac{6.0}{12} = 0.5 \text{ s}$$

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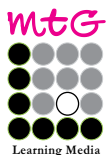
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Now, magnetic field, $B = \frac{4\pi^2 I}{mT^2}$

Here, $I = 7.8 \times 10^{-6} \text{ kg m}^2$,
 $m = 5.8 \times 10^{-2} \text{ A m}^2$

$$\therefore B = \frac{4 \times (3.14)^2 \times 7.8 \times 10^{-6}}{5.8 \times 10^{-2} \times (0.5)^2} = 0.021 \text{ T}$$

3. (d): Torque, $\vec{\tau} = \vec{m} \times \vec{B} = mB \sin\theta$
 and magnetic potential energy

$$U_m = -\vec{m} \cdot \vec{B} = -mB \cos\theta$$

At $\theta = 0^\circ$ the dipole will be in most stable position

$$\tau = mB \sin\theta = mB \sin 0 = 0$$

$$\text{and } U_m = -mB \cos\theta = -mB \cos 0 = -mB$$

4. (c): Here, $N = 900$ turns, $A = 2 \times 10^{-4} \text{ m}^2$,
 $m_s = 0.6 \text{ A m}^2$

The magnetic moment of solenoid

$$m_s = NIA$$

The current flowing through the solenoid is

$$I = \frac{m_s}{NA} = \frac{0.6}{900 \times 2 \times 10^{-4}} = 3.33 \text{ A}$$

5. (c): Here, $m = 0.6 \text{ A m}^2$, $r = 75 \text{ cm} = 0.75 \text{ m}$

$$B_{\text{axial}} = \frac{\mu_0}{4\pi} \cdot \left(\frac{2m}{r^3} \right) = 10^{-7} \times \frac{2 \times 0.6}{(0.75)^3}$$

$$\therefore B_{\text{axial}} = 2.84 \times 10^{-7} \text{ T} = 0.284 \mu\text{T}$$

6. (a): Since intensity of magnetisation (M) of a paramagnetic material is given by

$$M = C \frac{B}{T} = C\mu_0 \frac{H}{T} \text{ as } \frac{C\mu_0}{T} \text{ is constant.}$$

Then $M \propto H$

Hence, the M_H curve will be a straight line with the slope $C\mu_0 \frac{H}{T}$.

7. (a): Superconductors are most exotic diamagnetic materials. When these materials cooled to very low temperatures, which exhibits both perfect conductivity and perfect diamagnetism.

8. (d): Here, $n = 750$ turns, $A = 5 \times 10^{-4} \text{ m}^2$, $I = 3 \text{ A}$
 Magnetic moment,

$$m = nIA = 750 \times 3 \times 5 \times 10^{-4} = 11250 \times 10^{-4} \\ = 1.125 \text{ J T}^{-1} \text{ along the axis of solenoid.}$$

9. (d): Here, $n = 25$ turns, $r = 12 \text{ cm}$, $B = 0.5 \text{ T}$
 Since the coil is placed in uniform magnetic field normal to the plane of the coil.
 Hence the angle between magnetic moment and magnetic field direction is zero (i.e. $\theta = 0$)

$$\tau = mB \sin\theta = mB \sin 0$$

$$\Rightarrow \tau = 0$$

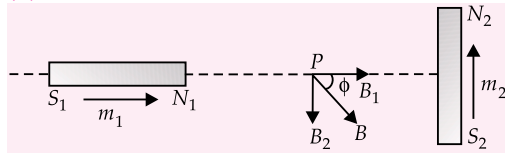
10. (a): Here, $\chi = -1$

$$\text{then } \mu_r = 1 + \chi$$

$$\mu_r = 1 + (-1) = 1 - 1 = 0$$

Since, magnetic susceptibility of given material is less than one. Hence, the given magnetic material is a diamagnetic material.

11. (d):



Let point P be a midpoint between the dipoles. The point P will be in end-on position with respect to one dipole and in broad-side position with respect to the other.

$$\therefore B_1 = \frac{\mu_0}{4\pi} \frac{2m_1}{r_1^3} = \frac{10^{-7} \times 2 \times 2}{(1)^3} = 4 \times 10^{-7} \text{ T}$$

$$\text{and } B_2 = \frac{\mu_0}{4\pi} \frac{m_2}{r_2^3} = \frac{10^{-7} \times 2}{(1)^3} = 2 \times 10^{-7} \text{ T}$$

As B_1 and B_2 are perpendicular to each other, therefore the resultant magnetic field at point P is

$$B = \sqrt{B_1^2 + B_2^2} = \sqrt{(4 \times 10^{-7})^2 + (2 \times 10^{-7})^2} \\ = 10^{-7} \sqrt{16 + 4} = 10^{-7} \sqrt{20} = 2\sqrt{5} \times 10^{-7} \text{ T}$$

12. (d): On the axis of the magnet

$$B = \frac{\mu_0}{4\pi} \cdot \frac{2m}{d^3}$$

$$\text{Here, } \frac{\mu_0}{4\pi} = 10^{-7} \text{ A m}^{-2}, m = 0.48 \text{ J T}^{-1},$$

$$d = 10 \text{ cm} = 0.1 \text{ m} \therefore B = \frac{10^{-7} \times 2 \times 0.48}{(0.1)^3}$$

$$= 0.96 \times 10^{-4} \text{ T, along S-N direction.}$$

13. (a): Here, $m = 0.39 \text{ J T}^{-1}$, $d = 20 \text{ cm} = 0.2 \text{ m}$
 On the equatorial line of magnet

$$B = \frac{\mu_0}{4\pi} \cdot \frac{m}{d^3} \\ = 10^{-7} \times \frac{0.39}{(0.2)^3} = \frac{0.39 \times 10^{-7}}{2^3 \times 10^{-3}} \\ = 0.049 \times 10^{-4} \text{ T} = 0.049 \text{ G along N-S direction}$$

14. (a): Here, $H_E = 0.16 \text{ G} = 0.16 \times 10^{-4} \text{ T}$.
 dip angle, $\delta = 60^\circ$

Then, magnitude of earth's field.

$$B_E = \frac{H_E}{\cos\delta} = \frac{0.16 \times 10^{-4}}{\cos 60^\circ}, B_E = \frac{0.16 \times 10^{-4}}{1/2} \\ = 0.32 \times 10^{-4} \text{ T} = 0.32 \text{ G}$$

15. (c) : Here, $M_1 = 10 \text{ A m}^{-1}$, $B_1 = 0.8 \text{ T}$, $T_1 = 4 \text{ K}$,
 $B_2 = 0.3 \text{ T}$, $T_2 = 16 \text{ K}$, $M_2 = ?$

Then, for paramagnetic materials,

$$\text{magnetisation } (M) = C \frac{B_0}{T} \quad (\text{Curie's law})$$

$$\text{Now, in the first case, } M_1 = \frac{CB_{01}}{T_1} \quad \dots(i)$$

$$\text{and in the second case, } M_2 = \frac{CB_{02}}{T_2} \quad \dots(ii)$$

Dividing equation (i) by (ii), we get

$$\frac{M_1}{M_2} = \frac{B_{01}}{B_{02}} \cdot \frac{T_2}{T_1}$$

$$\text{or } \frac{M_1}{M_2} = \frac{0.8}{0.3} \times \frac{16}{4} \quad \text{or } \frac{10}{M_2} = \frac{8}{3} \times 4$$

$$\text{or } M_2 = \frac{10 \times 3}{8 \times 4} = \frac{15}{16} \text{ A m}^{-1}$$

16. (d) : On the axis of a magnetic dipole magnetic induction is

$$B = \frac{\mu_0}{4\pi} \times \frac{2m}{r^3}$$

$$\text{Here, } r = 1 \text{ \AA} = 10^{-10} \text{ m}, m = 1.4 \times 10^{-26} \text{ A m}^{-2}$$

$$\text{and } \frac{\mu}{4\pi} = 10^{-7} \text{ N A}^{-2}$$

$$\therefore B = \frac{10^{-7} \times 2 \times 1.4 \times 10^{-26}}{(10^{-10})^3}$$

$$= \frac{10^{-7} \times 2.8 \times 10^{-26}}{10^{-30}} = 2.8 \times 10^{-3} \text{ T} = 2.8 \text{ mT}$$

17. (a) : Here, $l = 50 \text{ cm} = 0.5 \text{ m}$, $M = 10^6 \text{ A m}^{-1}$

$$\text{As } M = \frac{\text{magnetisation current } (I_M)}{(\text{length})l}$$

$$\therefore I_M = M \times l = 10^6 \times 0.5 = 5 \times 10^5 \text{ A}$$

18. (c) : Core of electromagnets are made of soft iron that is a ferromagnetic material with high permeability and low retentivity.

19. (b) : The volume of the cubic domain
 $V = (2 \mu\text{m})^3 = (2 \times 10^{-6} \text{ m})^3 = 8 \times 10^{-18} \text{ m}^3 = 8 \times 10^{-12} \text{ cm}^3$
 Also mass = volume \times density
 $= 8 \times 10^{-12} \text{ cm}^3 \times 7.9 \text{ g cm}^{-3} = 63.2 \times 10^{-12} \text{ g}$
 Now the Avogadro number (6.023×10^{23}) of iron atoms have a mass of 55 g.

Hence the number of atoms in the domain are

$$N = \frac{63.2 \times 10^{-12} \times 6.023 \times 10^{23}}{55} = 6.92 \times 10^{11} \text{ atoms}$$

20. (c) : Here, $\chi_{m_1} = 0.0075$,
 $T_1 = -73^\circ\text{C} = (-73 + 273) \text{ K} = 200 \text{ K}$
 $\chi_{m_2} = ?$, $T_2 = -173^\circ\text{C} = (-173 + 273) \text{ K} = 100 \text{ K}$
 For paramagnetic material magnetic susceptibility

$$\chi_m \propto \frac{1}{T} \Rightarrow \frac{\chi_{m_2}}{\chi_{m_1}} = \frac{T_1}{T_2} = \frac{200}{100} = 2$$

$$\therefore \chi_{m_2} = 2\chi_{m_1} = 2 \times 0.0075 = 0.015$$

21. (b) : Bismuth, copper, lead and silicon all are having the property of diamagnetic as in the atoms of these material have resultant magnetic moment zero.

22. (d) : The volume of the cubic domain is

$$V = (1.5 \times 10^{-6} \text{ m})^3 = 3.38 \times 10^{-18} \text{ m}^3$$

$$= 3.38 \times 10^{-12} \text{ cm}^3$$

Number of atoms in domain

$$N = 5 \times 10^{10} \text{ atoms}$$

Since each iron atom has a dipole moment,

$$m = 8 \times 10^{-24} \text{ A m}^2$$

$$m_{\text{max}} = \text{net dipole moment for all atoms}$$

$$= N \times m$$

$$= 5 \times 10^{10} \times 8 \times 10^{-24}$$

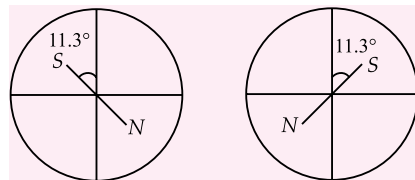
$$= 40 \times 10^{-14} = 4 \times 10^{-13} \text{ A m}^2.$$

Now the consequent magnetisation

$$M_{\text{max}} = \frac{m_{\text{max}}}{\text{Domain volume}}$$

$$= \frac{4 \times 10^{-13} \text{ A m}^2}{3.38 \times 10^{-18} \text{ m}^3} = 1.18 \times 10^5 \text{ A m}^{-1}$$

23. (a) :



Since the axis of the magnetic dipole placed at the centre of earth makes an angle of 11.3° with the axis of earth, the two possibilities arise as shown in above figure. Hence, the declination varies between 11.3° W to 11.3° E .

24. (d) : Here, $H = 1500 \text{ A m}^{-1}$, $\phi = 2.4 \times 10^{-5} \text{ weber}$
 $A = 0.5 \text{ cm}^2 = 0.5 \times 10^{-4} \text{ m}^2$

$$\therefore B = \frac{\phi}{A} = \frac{2.4 \times 10^{-5}}{0.5 \times 10^{-4}} = 4.8 \times 10^{-1} \text{ T}$$

$$\text{and } \mu = \frac{B}{H} = \frac{4.8 \times 10^{-1}}{1500} = 3.2 \times 10^{-4} \text{ T m A}^{-1}$$

So relative permeability

$$\mu_r = \frac{\mu}{\mu_0} = \frac{3.2 \times 10^{-4}}{4\pi \times 10^{-7}} = 0.255 \times 10^3 = 255$$

25. (c) : Here, $N = 100$, $r = 10 \text{ cm} = 0.10 \text{ m}$, $I = 5 \text{ A}$,
 $B = 0.5 \text{ T}$, $\theta = 90^\circ - 60^\circ = 30^\circ$
 Area of the coil, $A = \pi r^2 = 3.14 \times (0.1)^2$
 $\tau = NIB \sin \theta$

$$= 100 \times 5 \times 0.5 \times 3.14 \times (0.1)^2 \times \sin 30^\circ$$

$$= 3.931 \text{ N m}$$

26. (a): In solenoid, H field,

$$H = nI \text{ and } B \text{ field,}$$

$$B = \mu_0 \mu_r nI$$

Now the core is heated beyond the Curie temperature T_c , due to that μ_r decrease and hence B will also decrease.

27. (b): For circular coil C_1 , $n_1 = \frac{L}{2\pi R}$

$$\text{and magnetic moment } M_1 = n_1 I A_1$$

$$= \frac{L}{2\pi R} I \pi R^2 = \frac{LIR}{2}$$

For square coil C_2

$$n_2 = \frac{L}{4a}$$

$$\text{and magnetic moment } M_2 = n_2 I A_2$$

$$= \frac{L}{4a} I \times a^2 = \frac{LIa}{4}$$

Now moment of inertia about an axis through the

diameter of circular coil $I_1 = \frac{MR^2}{2}$ and moment

of inertia of square coil about an axis passing through its centre and parallel to edge of square

$$I_2 = \frac{Ma^2}{12}$$

Then, frequency of oscillation of C_1 , $\omega_1 = \sqrt{\frac{M_1 B}{I_1}}$

and frequency of oscillation of C_2 , $\omega_2 = \sqrt{\frac{M_2 B}{I_2}}$

$$\text{as } \omega_1^2 = \omega_2^2 \Rightarrow \frac{M_1}{I_1} = \frac{M_2}{I_2}$$

$$\Rightarrow \frac{\frac{LIR}{2}}{\frac{MR^2}{2}} = \frac{\frac{LIa}{4}}{\frac{Ma^2}{12}} \Rightarrow a = 3R$$

28. (b): Here, $B_V = \frac{\mu_0}{4\pi} \frac{2m \cos \theta}{r^3}$

$$B_H = \frac{\mu_0}{4\pi} \frac{m \sin \theta}{r^3}$$

and

$$\delta = 45^\circ$$

$$\therefore \tan \delta = \frac{B_V}{B_H}$$

$$\therefore \tan 45^\circ = \frac{2 \cos \theta}{\sin \theta} = 2 \cot \theta$$

$$\text{or } 1 = \frac{2}{\tan \theta} \Rightarrow \tan \theta = 2$$

or $\theta = \tan^{-1}(2)$ is the loci of points.

29. (c): Here, $\vec{m} = 30 \hat{j} \text{ A m}^2$ and $\vec{B} = (2\hat{i} + 5\hat{j}) \text{ T}$.

$$\text{Since } \vec{\tau} = \vec{m} \times \vec{B}$$

$$= 30 \hat{j} \times (2\hat{i} + 5\hat{j}) = 60 \hat{j} \times \hat{i} + 150 \hat{j} \times \hat{j} = 60(-\hat{k}) + 150 \times 0$$

$$= -60 \hat{k} \text{ N m} \quad [\because \hat{j} \times \hat{i} = -\hat{k} \text{ and } \hat{j} \times \hat{j} = 0]$$

30. (b): Since $B_H = B \cos \delta$

$$\text{Here, } B = 4 \times 10^{-5} \text{ T, } B_H = 2 \times 10^{-5} \text{ T}$$

$$\therefore \cos \delta = \frac{B_H}{B} = \frac{2 \times 10^{-5}}{4 \times 10^{-5}} = \frac{1}{2} = \cos 60^\circ$$

$$\Rightarrow \delta = 60^\circ$$

31. (d): Here, $N = 3000$, $A = 2 \times 10^{-4} \text{ m}^2$, $I = 6 \text{ A}$

$$\therefore M = N I A = 3000 \times 6 \times 2 \times 10^{-4} = 3.6 \text{ J T}^{-1}$$

32. (d): Here, $M = 0.355 \text{ J T}^{-1}$

$$B = 5.0 \times 10^{-2} \text{ T, } v = 2 \text{ Hz}$$

$$\text{As } v = \frac{1}{2\pi} \sqrt{\frac{MB}{I}} \quad \therefore v^2 = \frac{1}{4\pi^2} \frac{MB}{I}$$

$$\Rightarrow I = \frac{MB}{4\pi^2 v^2} = \frac{0.355 \times 5 \times 10^{-2}}{4 \times (3.14)^2 \times 2^2} = \frac{1.775 \times 10^{-2}}{157.75}$$

$$= 1.13 \times 10^{-4} \text{ kg m}^2$$

33. (c): Here, $\theta = 60^\circ$, $B_1 = 1.2 \times 10^{-2} \text{ T}$

$$\theta_1 = 30^\circ \text{ and } \theta_2 = 60^\circ - 30^\circ = 30^\circ$$

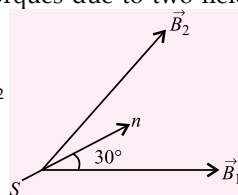
in stable equilibrium, torques due to two fields must be balanced

$$\text{i.e. } \tau_1 = \tau_2$$

$$\Rightarrow MB_1 \sin \theta_1 = MB_2 \sin \theta_2$$

$$\text{or } B_2 = B_1 \frac{\sin \theta_1}{\sin \theta_2}$$

$$= B_1 \frac{\sin 30^\circ}{\sin 30^\circ} = B_1 = 1.2 \times 10^{-2} \text{ T}$$



34. (c): Here, $r = 15 \text{ cm} = 15 \times 10^{-2} \text{ m}$

$$N = 3500 \text{ turns, } I = 1.2 \text{ A, } \mu_r = 800$$

Then number of turns/ length

$$(n) = \frac{N}{2\pi r} = \frac{3500}{2\pi \times 15 \times 10^{-2}}$$

$$\text{or } \beta = \mu_0 \mu_r nI$$

$$= 4\pi \times 10^{-7} \times 800 \times \frac{3500}{2\pi \times 15 \times 10^{-2}} \times 1.2 = 4.48 \text{ T}$$

35. (b): Here, $n = 500 \text{ turns/m}$

$$I = 1 \text{ A, } \mu_r = 500$$

$$\text{Magnetic intensity, } H = nI = 500 \text{ m}^{-1} \times 1 \text{ A}$$

$$= 500 \text{ A m}^{-1}$$

As $\mu_r = 1 + \chi$

where χ is the magnetic susceptibility of the material

$$\text{or } \chi = (\mu_r - 1)$$

$$\text{Magnetisation, } M = \chi H$$

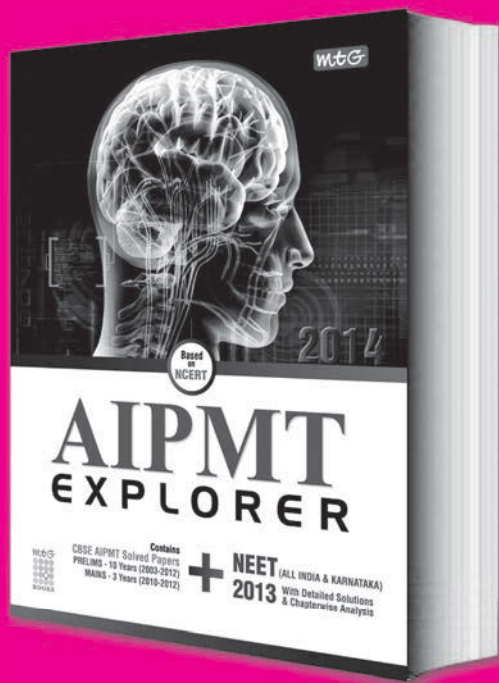
$$= (\mu_r - 1)H = (500 - 1) \times 500 \text{ A m}^{-1}$$

$$= 499 \times 500 \text{ A m}^{-1} = 2.495 \times 10^5 \text{ A m}^{-1}$$

$$\approx 2.5 \times 10^5 \text{ A m}^{-1}$$



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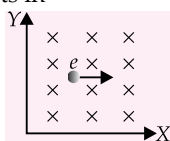


TARGET PMTs

PRACTICE QUESTIONS

Useful for All National and State Level PMTs

1. In the given figure, the electron enters into the magnetic field as shown. It deflects in
- +ve X direction
 - ve X direction
 - +ve Y direction
 - ve Y direction



2. The specific resistance of a wire is ρ , its volume is 3 m^3 and its resistance is 3Ω , then its length (in m) will be

- $\frac{1}{\sqrt{\rho}}$
- $\frac{3}{\sqrt{\rho}}$
- $\frac{\sqrt{3}}{\rho}$
- $\frac{\rho}{\sqrt{3}}$

3. In a straight conductor of uniform cross-section, charge q is flowing for time t . Let s be the specific charge of an electron. The momentum of all the free electrons per unit length of the conductor, due to their drift velocity only is

- $\left(\frac{q}{ts}\right)$
- $\left(\frac{q}{ts}\right)^2$
- $\sqrt{\left(\frac{q}{ts}\right)}$
- qts

4. An electric field is given by $\vec{E} = (y\hat{i} + x\hat{j}) \text{ N C}^{-1}$. The work done in moving a 1 C charge from

$\vec{r}_A = (2\hat{i} + 2\hat{j}) \text{ m}$ to $\vec{r}_B = (4\hat{i} + \hat{j}) \text{ m}$ is

- +8 J
- +4 J
- zero
- 4 J

5. Which of the following is called electrical energy tank?

- Resistor
- Inductor
- Capacitor
- Motor

6. A long wire carries a steady current. It is bent into a circle of one turn and the magnetic field at the centre of the coil is B . It is then bent into a circular loop of n turns. The magnetic field at the centre of

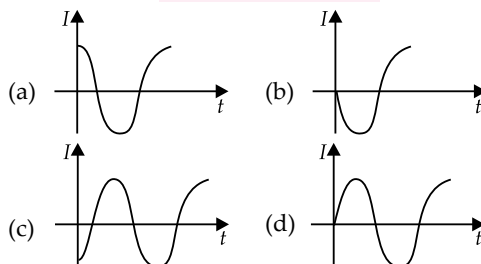
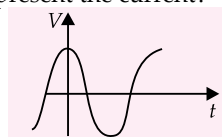
the coil will be

- nB
- n^2B
- $2nB$
- $2n^2B$

7. A fan works on the principle of

- electric dynamo
- electric motor
- transformer
- none of these

8. The voltage across a pure inductor is represented in figure. Which one of the following curves in figure will represent the current?



9. In an electromagnetic wave, the amplitudes of electric and magnetic fields are 100 V m^{-1} and 0.265 A m^{-1} . The maximum rate of energy flow per unit surface area is

- 26.5 W m^{-2}
- 36.5 W m^{-2}
- 46.7 W m^{-2}
- 765 W m^{-2}

10. In Young's double slit experiment, intensity at a point is $(1/4)^{\text{th}}$ of the maximum intensity. Angular position of this point will be

- $\sin^{-1}(\lambda/4d)$
- $\sin^{-1}(\lambda/2d)$
- $\sin^{-1}(\lambda/3d)$
- $\sin^{-1}(\lambda/4d)$

11. The time dependence of a physical quantity P is given by $P = P_0 e^{-\alpha t^2}$ where α is a constant and t is time. Then constant α is having dimension of

- [T]
- [T⁻²]
- [T⁻¹]
- [T²]

12. The velocity of a particle is $v = v_0 + gt + ft^2$. If its position is $x = 0$ at $t = 0$, then its displacement after unit time ($t = 1$ s) is

(a) $v_0 - g/2 + f$ (b) $v_0 + g/2 + 3f$
(c) $v_0 + g/2 + f/3$ (d) $v_0 + g + f$

13. Two vectors \vec{a} and \vec{b} are at an angle of 60° with each other. Their resultant makes an angle of 45° with \vec{a} . If $|\vec{b}| = 2$ unit, then $|\vec{a}|$ is

(a) $\sqrt{3}$ unit (b) $(\sqrt{3} - 1)$ unit
(c) $(\sqrt{3} + 1)$ unit (d) $\frac{\sqrt{3}}{2}$ unit

14. The equation of a projectile is $y = \sqrt{3}x - \frac{gx^2}{2}$. The angle of projection is given by

(a) $\tan^{-1}\left(\frac{1}{\sqrt{3}}\right)$ (b) $\tan^{-1}(\sqrt{3})$
(c) $\frac{\pi}{2}$ (d) zero

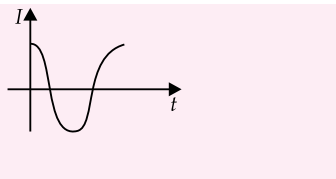
15. A motorcycle moving with a velocity of 72 km h^{-1} on a flat road takes a turn on the road at a point where the radius of curvature of the road is 20 m . The acceleration due to gravity is 10 m s^{-2} . In order to avoid skidding, it must not bent with respect to the vertical plane by an angle greater than

(a) $\tan^{-1}(2)$ (b) $\tan^{-1}(6)$
(c) $\tan^{-1}(4)$ (d) $\tan^{-1}(8)$

16. When a man increases his speed by 2 m s^{-1} , he finds that his kinetic energy is doubled, the original speed of the man is

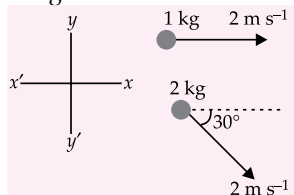
(a) $2(\sqrt{2} - 1) \text{ m s}^{-1}$ (b) $2(\sqrt{2} + 1) \text{ m s}^{-1}$
(c) 4.5 m s^{-1} (d) None of these

17. Magnetic field induction at the centre O of a square loop of side ' a ' carrying current I as shown in figure is



(a) $\frac{\mu_0 I}{\sqrt{2}\pi a}$ (b) $\frac{2\mu_0 I}{\pi a}$ (c) $\frac{\mu_0 I}{2\pi a}$ (d) zero

18. Find the velocity of centre of mass of the system shown in the figure.

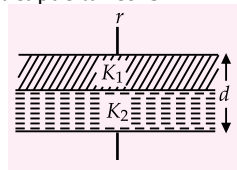


(a) $\left(\frac{2+2\sqrt{3}}{3}\right)\hat{i} - \frac{2}{3}\hat{j}$ (b) $4\hat{i}$
(c) $\left(\frac{2-2\sqrt{3}}{3}\right)\hat{i} - \frac{1}{3}\hat{j}$ (d) None of these

19. Three rods each of length L and mass M are placed along X , Y and Z axes in such a way that one end of each rod is at the origin. The moment of inertia of the system about Z -axis is

(a) $\frac{ML^2}{3}$ (b) $\frac{2ML^2}{3}$
(c) $\frac{3ML^2}{2}$ (d) $\frac{2ML^2}{12}$

20. A parallel plate capacitor of plate area A , separation d is filled with dielectrics as shown in the given figure. The dielectric constants are K_1 and K_2 . Net capacitance is



(a) $\frac{\epsilon_0 A}{d}(K_1 + K_2)$ (b) $\frac{\epsilon_0 A}{d}\left(\frac{K_1 + K_2}{K_1 K_2}\right)$
(c) $\frac{2\epsilon_0 A}{d}\left(\frac{K_1 K_2}{K_1 + K_2}\right)$ (d) $\frac{2\epsilon_0 A}{d}\left(\frac{K_1 + K_2}{K_1 K_2}\right)$

21. Two bodies A and B are placed in an evacuated vessel maintained at a temperature of 27°C . The temperature of A is 327°C and that of B is 227°C . The ratio of heat loss from A to B is about

(a) 2 : 1 (b) 4 : 1
(c) 1 : 2 (d) 1 : 4

22. If one mole of a monoatomic gas $\left(\gamma = \frac{5}{3}\right)$ is

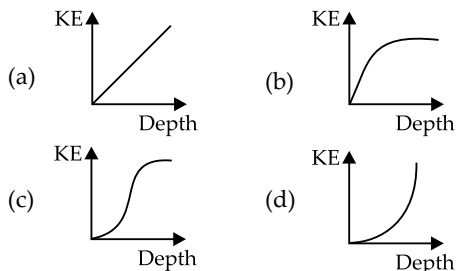
mixed with one mole of a diatomic gas $\left(\gamma = \frac{7}{5}\right)$, the value of γ for the mixture is

(a) 1.40 (b) 1.50 (c) 1.53 (d) 3.07

23. A gas undergoes a process in which its pressure P and volume V are related as $VP^n = \text{constant}$. The bulk modulus for the gas in this process is

(a) nP (b) $P^{1/n}$ (c) $\frac{P}{n}$ (d) P^n

24. Which one of the following diagrams correctly shows the change in kinetic energy of an iron sphere falling freely in a lake having sufficient depth to impart it a terminal velocity?



25. Two radioactive nuclei A and B have disintegration constants λ_A and λ_B and initially N_A and N_B number of nuclei of them are there. The time after which their undisintegrated nuclei are same is

(a) $\frac{\lambda_A \lambda_B}{(\lambda_A - \lambda_B)} \ln \left(\frac{N_B}{N_A} \right)$ (b) $\frac{1}{(\lambda_A + \lambda_B)} \ln \left(\frac{N_B}{N_A} \right)$
 (c) $\frac{1}{(\lambda_B - \lambda_A)} \ln \left(\frac{N_B}{N_A} \right)$ (d) $\frac{1}{(\lambda_A - \lambda_B)} \ln \left(\frac{N_B}{N_A} \right)$

26. The magnitude of angular momentum, orbit radius and frequency of revolution of electron in hydrogen atom corresponding to quantum number n are L , r , and ν respectively. Then, according to Bohr's theory of hydrogen atom, is constant for all orbits.

(a) $\nu r^2 L$ (b) $\nu r L$ (c) $\nu^2 r L$ (d) $\nu r L^2$

27. If angle of incidence is twice the angle of refraction in a medium of refractive index μ , then angle of incidence is

(a) $2 \cos^{-1} \left(\frac{\mu}{2} \right)$ (b) $2 \sin^{-1} \left(\frac{\mu}{2} \right)$
 (c) $2 \cos^{-1}(\mu)$ (d) $2 \sin^{-1}(\mu)$

28. A telescope uses light having wavelength 5000 \AA and lenses of focal lengths 2.5 cm and 30 cm . If the diameter of the aperture of the objective is 10 cm , then the resolving limit of telescope is

(a) $6.1 \times 10^{-6} \text{ rad}$ (b) $5.0 \times 10^{-6} \text{ rad}$
 (c) $8.3 \times 10^{-4} \text{ rad}$ (d) $7.3 \times 10^{-3} \text{ rad}$

29. An inductive coil has a resistance of 100Ω . When an AC signal of frequency 1000 Hz is applied to the coil, the voltage leads the current by 45° . The inductance of the coil is

(a) $\frac{1}{10\pi} \text{ H}$ (b) $\frac{1}{20\pi} \text{ H}$
 (c) $\frac{1}{40\pi} \text{ H}$ (d) $\frac{1}{60\pi} \text{ H}$

30. Diameter of a plano-convex lens is 6 cm and thickness at the centre is 3 mm . If the speed of light in the material of the lens is $2 \times 10^8 \text{ m s}^{-1}$, the focal length of the lens is

(a) 15 cm (b) 20 cm
 (c) 30 cm (d) 10 cm

31. The number densities of electrons and holes in a pure germanium at room temperature are equal and its value is $3 \times 10^{16} \text{ m}^{-3}$. On doping with aluminium hole density increases to $4.5 \times 10^{22} \text{ m}^{-3}$. Then the electron density in doped germanium is

(a) $2 \times 10^{10} \text{ m}^{-3}$ (b) $5 \times 10^9 \text{ m}^{-3}$
 (c) $4.5 \times 10^9 \text{ m}^{-3}$ (d) $3 \times 10^9 \text{ m}^{-3}$

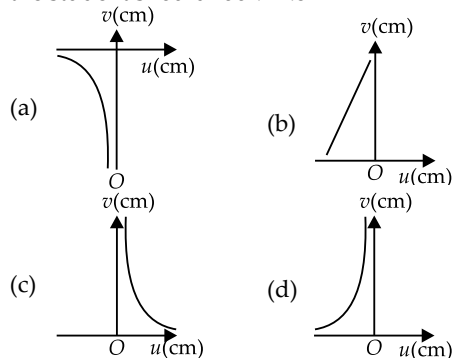
32. In short wave communication wave of which of the following frequencies will be reflected back by the ionospheric layer having electron density 10^{11} m^{-3} ?

(a) 2.85 MHz (b) 5.25 MHz
 (c) 12 MHz (d) 18 MHz

33. The volume occupied by an atom is greater than the volume of the nucleus by a factor of about

(a) 10^{15} (b) 10^5
 (c) 10^{10} (d) 10^{-15}

34. A student measures the focal length of a convex lens by putting an object pin at a distance u from the lens and measuring the distance v of the image pin. The graph between u and v plotted by the student should look like



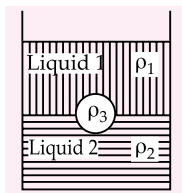
35. In a compound microscope, the intermediate image is

(a) virtual, erect and magnified
 (b) real, erect and magnified
 (c) real, inverted and magnified
 (d) virtual, inverted and magnified

36. A rod of length l and mass m is capable of rotating freely about an axis passing through a hole at the end. The period of oscillations of this physical pendulum is

(a) $2\pi \sqrt{\frac{l}{3g}}$ (b) $2\pi \sqrt{\frac{2l}{3g}}$
 (c) $2\pi \sqrt{\frac{l}{2g}}$ (d) $2\pi \sqrt{\frac{2l}{g}}$

37. The composition of two simple harmonic motions of equal periods at right angle to each other and with a phase difference of π results in the displacement of the particle along
 (a) circle (b) figure of eight
 (c) straight line (d) ellipse
38. The phase difference between two points separated by 1 m in a wave of frequency 120 Hz is 90° . The wave velocity will be
 (a) 720 m s^{-1} (b) 480 m s^{-1}
 (c) 240 m s^{-1} (d) 180 m s^{-1}
39. A jar is filled with two non-mixing liquids 1 and 2 having densities ρ_1 and ρ_2 respectively.



A solid ball, made of a material of density ρ_3 , is dropped in the jar. It comes to equilibrium in the position shown in the figure. Which of the following is true for ρ_1 , ρ_2 and ρ_3 ?

- (a) $\rho_1 < \rho_3 < \rho_2$ (b) $\rho_3 < \rho_1 < \rho_2$
 (c) $\rho_1 > \rho_3 > \rho_2$ (d) $\rho_1 < \rho_2 < \rho_3$
40. Assuming the sun to have a spherical outer surface of radius R , radiating like a black body at temperature $t^\circ\text{C}$, the power received by a unit surface (normal to the incident rays) at a distance r from the centre of the sun is
 (a) $\frac{4\pi R^2 \sigma t^4}{r^2}$ (b) $\frac{R^2 \sigma (t + 273)^4}{4\pi r^2}$
 (c) $\frac{16\pi R^2 \sigma t^4}{r^2}$ (d) $\frac{R^2 \sigma (t + 273)^4}{r^2}$
41. The de-Broglie wave present in fifth Bohr orbit is
 (a) (b)
 (c) (d)
42. When light of wavelength 300 nm falls on a photoelectric emitter, photoelectrons are liberated. For another emitter, however, light of 600 nm wavelength is sufficient for creating photo emission. What is the ratio of the work function of the two emitters?
 (a) 1 : 2 (b) 2 : 1
 (c) 4 : 1 (d) 1 : 4

43. The peak voltage in the output of a half wave diode rectifier fed with a sinusoidal signal without filter is 10 V. The D.C. component of the output voltage is

- (a) $\frac{10}{\sqrt{2}} \text{ V}$ (b) $\frac{10}{\pi} \text{ V}$
 (c) 10 V (d) $\frac{20}{\pi} \text{ V}$

44. Two point white dots are 1 mm apart on a black paper. They are viewed by eye of pupil diameter 3 mm. Approximately, what is the maximum distance at which these dots can be resolved by the eye?

(Take wavelength of light = 500 nm).

- (a) 5 m (b) 1 m
 (c) 6 m (d) 3 m
45. A car is fitted with a convex side-view mirror of focal length 20 cm. A second car 2.8 m behind the first car is overtaking the first car at a relative speed of 15 m s^{-1} . The speed of the image of the second car as seen in the mirror of the first one is

- (a) $\frac{1}{10} \text{ m s}^{-1}$ (b) $\frac{1}{15} \text{ m s}^{-1}$
 (c) 10 m s^{-1} (d) 15 m s^{-1}

46. Let T_1 and T_2 be the time periods of springs A and B when mass M is suspended from one end of each spring. If both springs are taken in series combination, the time period is T , then

- (a) $T = T_1 + T_2$ (b) $\frac{1}{T} = \frac{1}{T_1} + \frac{1}{T_2}$
 (c) $T^2 = T_1^2 + T_2^2$ (d) $\frac{1}{T^2} = \frac{1}{T_1^2} + \frac{1}{T_2^2}$

47. The angular velocity and the amplitude of a simple pendulum are ω and A respectively. At a displacement x from the mean position if its kinetic energy is T and potential energy is V , then the ratio of T to V is

- (a) $\frac{(A^2 - x^2 \omega^2)}{x^2 \omega^2}$ (b) $\frac{x^2 \omega^2}{(A^2 - x^2 \omega^2)}$
 (c) $\frac{(A^2 - x^2)}{x^2}$ (d) $\frac{x^2}{(A^2 - \omega^2)}$

48. What is the value of linear velocity, if $\vec{r} = 3\hat{i} - 4\hat{j} + \hat{k}$ and $\vec{\omega} = 5\hat{i} - 6\hat{j} + 6\hat{k}$?

- (a) $4\hat{i} - 13\hat{j} + 6\hat{k}$ (b) $18\hat{i} + 13\hat{j} - 2\hat{k}$
 (c) $6\hat{i} + 2\hat{j} - 3\hat{k}$ (d) $6\hat{i} - 2\hat{j} + 8\hat{k}$

49. Average density of the earth

- (a) does not depend on g
 (b) is a complex function of g
 (c) is directly proportional to g
 (d) is inversely proportional to g

50. Which of the following is wrongly matched?
 (a) Barometer-Pressure (b) Lactometer-Milk
 (c) Coulomb's law-charges
 (d) Humidity-Calorimeter

SOLUTIONS

1. (d): From Fleming's left-hand rule, the electron deflects in -ve Y-direction.

2. (b): Here, $R = 3 \Omega$ and $V = 3 \text{ m}^3$

$$\text{Since, } R = \frac{\rho l}{A} = \frac{\rho l}{V/l} = \frac{\rho l^2}{V} \quad [\because V = Al]$$

$$\text{or } l = \left(\frac{RV}{\rho} \right)^{1/2} = \left(\frac{3 \times 3}{\rho} \right)^{1/2} = \frac{3}{\sqrt{\rho}} \text{ m}$$

3. (a): $I = nAev_d$ or $v_d = \frac{I}{nAe} = \frac{q/t}{nAe} \dots(i)$

Number of free electrons per unit length of conductor,

$$N = \frac{nV}{l} = \frac{nAl}{l} = nA \dots(ii)$$

\therefore Momentum of all the free electrons per unit length of the conductor,

$$p = Nmv_d = nA \times m \times \frac{q/t}{nAe} = \frac{q/t}{(e/m)} = \frac{q}{ts}$$

4. (c): Here, $\vec{E} = (y\hat{i} + x\hat{j}) \text{ N C}^{-1}$.

A (2, 2) and B (4, 1)

$$\int_A^B dV = \int_A^B -\vec{E} \cdot d\vec{r} = - \int_{2,2}^{4,1} (y\hat{i} + x\hat{j}) \cdot (dx\hat{i} + dy\hat{j} + dz\hat{k})$$

$$V_B - V_A = - \int_{2,2}^{4,1} (ydx + xdy) = - \int_{2,2}^{4,1} d(xy) \\ = -[xy]_{2,2}^{4,1} = -(4 \times 1 - 2 \times 2) = -(4 - 4) = 0$$

$$\therefore W_{AB} = q(V_B - V_A) = 1(0) = \text{zero.}$$

5. (c): Capacitor stores electrical energy whereas inductor stores magnetic energy. Hence, capacitor is called the electrical energy tank.

6. (b): When wire of length l is bent into one turn circular coil of radius r , then $l = 2\pi r$ or $r = l/2\pi$
 \therefore Magnetic field at centre of coil

$$B = \frac{\mu_0 2\pi I}{4\pi r} = \frac{\mu_0 I}{2r} = \frac{\mu_0 I}{2 \times (l/2\pi)} = \frac{\mu_0 \pi I}{l} \dots(i)$$

When wire of length l is bent into n turns circular coil of radius r' , then; $l = 2\pi n r'$ or $r' = l/2\pi n$.

\therefore Magnetic field at centre of coil,

$$B' = \frac{\mu_0}{4\pi} \times \frac{2\pi n I}{r'} = \frac{\mu_0 n I}{2r'} \\ = \frac{\mu_0 n I}{2(l/2\pi n)} = \frac{n^2 \mu_0 \pi I}{l} = n^2 B \dots(ii)$$

From equations (i) and (ii), $B' = n^2 B$.

7. (b): A fan converts electrical energy into mechanical energy of rotation. Therefore, it works on the principle of electric motor.

8. (d): Comparison of graphs shows that in (d) alone, current lags behind the voltage by 90° which is true only in the case of a pure inductor.

9. (a): Here, amplitude of electric field,

$$E_0 = 100 \text{ V m}^{-1};$$

Amplitude of magnetic field,

$$H_0 = 0.265 \text{ A m}^{-1}.$$

We know that the maximum rate of energy flow per unit surface area is,

$$S = E_0 \times H_0 = 100 \times 0.265 = 26.5 \text{ W m}^{-2}.$$

10. (c): Since, $I = I_{\max} \cos^2 \frac{\phi}{2}$

$$\text{Here, } I = \frac{I_{\max}}{4}$$

$$\therefore \frac{I_{\max}}{4} = I_{\max} \cos^2 \frac{\phi}{2}$$

$$\Rightarrow \cos^2 \frac{\phi}{2} = \frac{1}{4}$$

$$\text{or } \cos \frac{\phi}{2} = \frac{1}{2}$$

$$\text{or } \frac{\phi}{2} = \cos^{-1} \left(\frac{1}{2} \right) = \frac{\pi}{3} \text{ rad}$$

$$\text{or } \phi = \frac{2\pi}{3} \text{ rad}$$

If Δx is the path difference between two waves, then

$$\frac{\phi}{2\pi} = \frac{\Delta x}{\lambda} \Rightarrow \Delta x = \frac{\lambda}{2\pi} \phi = \frac{\lambda}{2\pi} \times \frac{2\pi}{3} = \frac{\lambda}{3}$$

If angular separation is θ then $d \sin \theta = \Delta x = \lambda/3$

$$\text{or } \sin \theta = \frac{\lambda}{3d} \text{ or } \theta = \sin^{-1} \left(\frac{\lambda}{3d} \right)$$

11. (b): Here αt^2 is a dimensionless quantity.

Therefore, $[\alpha] = \left[\frac{1}{t^2} \right]$ and α has the dimension of $[T^{-2}]$.

12. (c): Given: velocity, $v = v_0 + gt + ft^2$

$$\text{As, } v = \frac{dx}{dt}, \text{ so } \int_0^x dx = \int_0^t v dt = \int_0^t (v_0 + gt + ft^2) dt$$

$$\text{or } x = v_0 t + gt^2/2 + ft^3/3$$

When $t = 1 \text{ s}$, then $x = v_0 + g/2 + f/3$

13. (b): Here, $|\vec{b}| = 2 \text{ unit}$, $\theta = 60^\circ$, $\phi = 45^\circ$

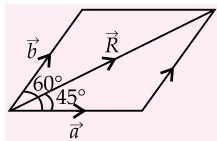
$$\therefore \tan \phi = \frac{|\vec{b}| \sin \theta}{|\vec{a}| + |\vec{b}| \cos \theta}$$

$$\therefore \tan 45^\circ = \frac{2 \sin 60^\circ}{|\vec{a}| + 2 \cos 60^\circ} = \frac{\sqrt{3}}{|\vec{a}| + 1}$$

$$1 = \frac{\sqrt{3}}{|\vec{a}| + 1}$$

$$\text{or } |\vec{a}| + 1 = \sqrt{3}$$

$$|\vec{a}| = (\sqrt{3} - 1) \text{ unit}$$



14. (b): Here, the equation of projectile is

$$y = \sqrt{3}x - \frac{gx^2}{2}$$

Comparing the given equation with

$$y = x \tan \theta - \frac{gx^2}{2v^2 \cos^2 \theta},$$

we get, $\tan \theta = \sqrt{3} \Rightarrow \theta = \tan^{-1}(\sqrt{3})$

15. (a): Using the formula for motorcycle not to skid

$$\theta = \tan^{-1} \left(\frac{v^2}{rg} \right)$$

Here, $r = 20 \text{ m}$, $v = 72 \text{ km h}^{-1} = 72 \times \frac{5}{18} = 20 \text{ m s}^{-1}$

and $g = 10 \text{ m s}^{-2}$

$$\therefore \theta = \tan^{-1} \left(\frac{20 \times 20}{20 \times 10} \right)$$

or $\theta = \tan^{-1}(2)$

16. (b): Let, $v_1 = v \text{ m s}^{-1}$, then $v_2 = (v + 2) \text{ m s}^{-1}$ and $K_2 = 2K_1$

Now, kinetic energy, $K = \frac{1}{2}mv^2 \Rightarrow K \propto v^2$

$$\text{or } \frac{K_1}{K_2} = \left(\frac{v_1}{v_2} \right)^2$$

$$\therefore \frac{1}{2} = \frac{v^2}{(v+2)^2} \quad (\because K_2 = 2K_1)$$

$$\Rightarrow v^2 + 4v + 4 = 2v^2$$

$$\Rightarrow v^2 - 4v - 4 = 0$$

$$\Rightarrow v = \frac{4 \pm \sqrt{16 + 16}}{2}$$

$$\text{or } v = \frac{4 \pm \sqrt{32}}{2} = 2(\sqrt{2} + 1) \text{ m s}^{-1}$$

17. (d): AB and DC, AD and BC are the two current carrying pairs. They are so situated that currents of each pair produce equal and opposite magnetic fields at the centre O of the loop. Hence, the resultant magnetic field induction at the centre O of the loop is zero.

18. (a): Here, $m_1 = 1 \text{ kg}$, $\vec{v}_1 = 2\hat{i} \text{ m s}^{-1}$

$$m_2 = 2 \text{ kg}, \vec{v}_2 = (2 \cos 30^\circ \hat{i} - 2 \sin 30^\circ \hat{j}) \text{ m s}^{-1}$$

$$\begin{aligned} \therefore \vec{v}_{\text{CM}} &= \frac{m_1 \vec{v}_1 + m_2 \vec{v}_2}{m_1 + m_2} \\ &= \frac{1 \times 2\hat{i} + 2(2 \cos 30^\circ \hat{i} - 2 \sin 30^\circ \hat{j})}{1 + 2} \\ &= \frac{2\hat{i} + 2\sqrt{3}\hat{i} - 2\hat{j}}{3} = \left(\frac{2 + 2\sqrt{3}}{3} \right) \hat{i} - \frac{2}{3} \hat{j} \end{aligned}$$

19. (b): Moment of inertia of a rod about one end

$$I_X = I_Y = \frac{ML^2}{3}$$

Hence, moment of inertia of the system about Z-axis

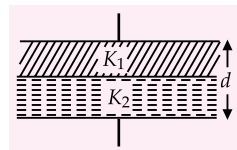
$$I = I_X + I_Y + I_Z$$

$$\therefore I = \frac{ML^2}{3} + \frac{ML^2}{3} + 0 = \frac{2ML^2}{3}$$

20. (c): The arrangement shown in the figure is equivalent to two capacitors of capacitances C_1 and C_2 connected in series, where

$$C_1 = \frac{K_1 \epsilon_0 A}{d/2}$$

$$C_2 = \frac{K_2 \epsilon_0 A}{d/2}$$



$$\begin{aligned} \frac{1}{C_s} &= \frac{1}{C_1} + \frac{1}{C_2} = \frac{d}{2K_1 \epsilon_0 A} + \frac{d}{2K_2 \epsilon_0 A} \\ &= \frac{d}{2\epsilon_0 A} \left(\frac{K_2 + K_1}{K_1 K_2} \right) \end{aligned}$$

$$\therefore C_s = \frac{2\epsilon_0 A}{d} \left(\frac{K_2 K_1}{K_1 + K_2} \right)$$

21. (a): Since net heat loss by a body per second,

$$E = \epsilon \sigma A (T^4 - T_0^4)$$

$$\therefore \frac{E_1}{E_2} = \frac{T_1^4 - T_0^4}{T_2^4 - T_0^4} = \frac{(327 + 273)^4 - (27 + 273)^4}{(227 + 273)^4 - (27 + 273)^4}$$

$$= \frac{(600)^4 - (300)^4}{(500)^4 - (300)^4} = \frac{10^8(1296 - 81)}{10^8(625 - 81)} = \frac{1215}{544} = 2.23 \approx 2:1$$

$$22. (b): \gamma_{\text{mix}} = \frac{\frac{n_1 \gamma_1}{\gamma_1 - 1} + \frac{n_2 \gamma_2}{\gamma_2 - 1}}{\frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}}$$

$$= \frac{1 \times \frac{5}{3} + 1 \times \frac{7}{5}}{\left[\frac{5}{3} - 1 \right] + \left[\frac{7}{5} - 1 \right]} = \frac{3}{2} = 1.5$$

23. (c) : $VP^n = \text{constant}$

$$\therefore VP^n = (V + \Delta V)(P + \Delta P)^n$$

$$= VP^n \left(1 + \frac{\Delta V}{V} \right) \left(1 + n \frac{\Delta P}{P} \right)$$

$$\Rightarrow 1 = 1 + \frac{\Delta V}{V} + n \frac{\Delta P}{P} + n \frac{\Delta V}{V} \frac{\Delta P}{P}$$

$$\text{or } \frac{\Delta V}{V} = -n \frac{\Delta P}{P}, \quad (\text{neglecting the product})$$

$$\left(n \frac{\Delta V}{V} \frac{\Delta P}{P} \right)$$

Now, Bulk modulus of the gas,

$$k = \frac{-\Delta P}{\Delta V/V} = \frac{P}{n}$$

24. (b): The velocity of sphere goes on increasing till it attains its terminal velocity and then continues moving with it. Same is the case with its K.E. $\left(= \frac{1}{2}mv^2 \right)$

Hence (b) is correct.

25. (c) : Suppose after time t , nuclei A and B have same undisintegrated nuclei

$$\therefore N = N_0 e^{-\lambda t}$$

$$\Rightarrow N_A e^{-\lambda_A t} = N_B e^{-\lambda_B t}$$

$$\therefore e^{(\lambda_B - \lambda_A)t} = \frac{N_B}{N_A}$$

$$\text{or } t = \frac{1}{(\lambda_B - \lambda_A)} \ln \left(\frac{N_B}{N_A} \right)$$

26. (b): For hydrogen atom,

$$r \propto n^2, L \propto n$$

$$\text{Also, } L = mrv^2\omega = mrv^2 2\pi\nu$$

$$\text{or } \nu = \frac{L}{2\pi m r^2} \therefore \nu \propto \frac{n}{(n^2)^2} = \frac{1}{n^3}$$

$$\therefore \nu r L \propto \frac{1}{n^3} \cdot n^2 \cdot n = 1$$

$\Rightarrow \nu r L$ is constant for all orbits.

$$\nu r^2 L \propto \frac{1}{n^3} \cdot n^4 \cdot n = n^2$$

$$\nu^2 r L \propto \frac{1}{n^6} \cdot n^2 \cdot n = \frac{1}{n^3}$$

$$\nu r L^2 \propto \frac{1}{n^3} \cdot n^2 \cdot n^2 = n$$

27. (a) : According to Snell's law

$$\text{Refractive index, } \mu = \frac{\sin i}{\sin r}$$

$$\text{Given, } i = 2r$$

$$\therefore \mu = \frac{\sin 2r}{\sin r}$$

$$\text{or } \mu = \frac{2 \sin r \cos r}{\sin r} \quad \text{or } r = \cos^{-1} \left(\frac{\mu}{2} \right)$$

$$\Rightarrow i = 2 \cos^{-1} \left(\frac{\mu}{2} \right)$$

28. (a) : Here, $\lambda = 5000 \text{ \AA} = 5000 \times 10^{-10} \text{ m}$.

$$f_e = 2.5 \text{ cm}, f_0 = 30 \text{ cm and } a = 10 \text{ cm} = 0.1 \text{ m}$$

$$\therefore \text{Resolving limit, } \theta = \frac{1.22\lambda}{a} = \frac{1.22 \times (5000 \times 10^{-10})}{0.1} \\ = 6.1 \times 10^{-6} \text{ rad}$$

29. (b): Since, $\tan \phi = \frac{X_L}{R}$

$$\text{Here, } \phi = 45^\circ, R = 100 \Omega, \nu = 1000 \text{ Hz}$$

$$\therefore \tan 45^\circ = 1 = \frac{L\omega}{R}$$

$$\text{or } L = \frac{R}{\omega} = \frac{R}{2\pi\nu} = \frac{100}{2\pi \times 1000}$$

$$\Rightarrow L = \frac{1}{20\pi} \text{ H.}$$

30. (c) : Here, $r = \frac{6}{2} = 3 \text{ cm}, t = 3 \text{ mm} = 0.3 \text{ cm}$.

If R_2 is radius of curvature of convex surface, then $2R_2 t = r^2$

$$\therefore R_2 = \frac{r^2}{2t} = \frac{3 \times 3}{2 \times 0.3} = 15 \text{ cm}, R_1 = \infty$$

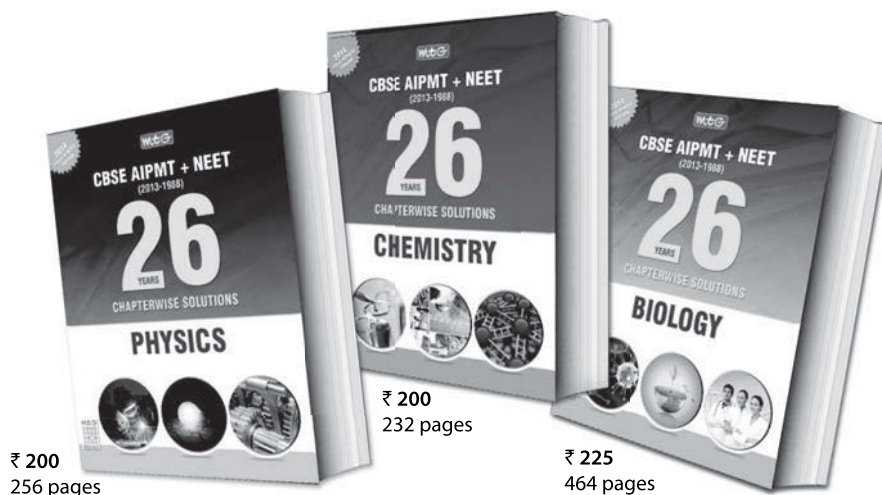
$$\text{and } \mu = \frac{c}{v} = \frac{3 \times 10^8}{2 \times 10^8} = \frac{3}{2}$$

$$\text{As } \frac{1}{f} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\therefore \frac{1}{f} = \left(\frac{3}{2} - 1 \right) \left(\frac{1}{\infty} - \frac{1}{-15} \right) = \frac{1}{30}$$

$$\Rightarrow f = 30 \text{ cm}$$

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HIGHLIGHTS:

- Chapter-wise questions of last 25 years' (2012-1988) of CBSE-PMT
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31. (a): Here, $n_i = 3 \times 10^{16} \text{ m}^{-3}$ and $n_h = 4.5 \times 10^{22} \text{ m}^{-3}$

Since $n_e n_h = n_i^2$

\therefore electron density in doped germanium,

$$n_e = \frac{n_i^2}{n_h} = \frac{(3 \times 10^{16})^2}{4.5 \times 10^{22}} = 2 \times 10^{10} \text{ m}^{-3}$$

32. (a): Here, $N_{\max} = 10^{11} \text{ m}^{-3}$

\therefore reflected back frequency by the ionospheric layer

$$\nu_c = 9(N_{\max})^{1/2} = 9 \times (10^{11})^{1/2} = 2.85 \text{ MHz.}$$

33. (a): Since, order of size of atom = 10^{-10} m and order of size of nucleus = 10^{-15} m .

$$\therefore \frac{\text{Volume occupied by an atom}}{\text{Volume of nucleus}} = \frac{(10^{-10})^3}{(10^{-15})^3} = 10^{15}$$

34. (d): From the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ (constant)

Here u is always negative, v is positive.

\therefore Choice (d) is correct.

35. (c): The intermediate image in a compound microscope is real, inverted and magnified.

36. (b): Here, length of rod = l ,

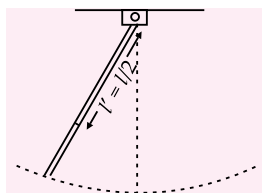
mass of rod = m

\therefore Moment of inertia of rod about one end

$$I = \frac{1}{3} ml^2.$$

Since rod is uniform hence length of centre of

mass, $l' = \frac{l}{2}$.



\therefore Time period of oscillations,

$$T = 2\pi \sqrt{\frac{I}{mg l'}} = 2\pi \sqrt{\frac{\frac{1}{3} ml^2}{mg \frac{l}{2}}} = 2\pi \sqrt{\frac{2l}{3g}}.$$

37. (c): Here, two SHM's are having phase difference, $\phi = \pi \text{ rad}$.

\therefore Their equation of motion,

$$x = A \sin \omega t \quad \dots(i)$$

$$\text{and } y = B \sin(\omega t + \pi) = -B \sin \omega t \quad \dots(ii)$$

\therefore From equations (i) and (ii),

$$\frac{x}{A} = -\frac{y}{B} \text{ or } y = -\frac{B}{A} x$$

This is the equation of a straight line.

\Rightarrow option (c) is correct.

38. (b): Here, $\Delta x = 1 \text{ m}$, $\phi = 90^\circ = \frac{\pi}{2} \text{ rad}$, $\nu = 120 \text{ Hz}$

$$\text{As } \phi = \frac{2\pi}{\lambda} \times \Delta x$$

$$\text{or } \frac{\pi}{2} = \frac{2\pi}{\lambda} \times 1$$

$$\Rightarrow \lambda = 4 \text{ m}$$

$$\therefore \text{Wave velocity, } v = \nu \lambda = 120 \times 4 = 480 \text{ m s}^{-1}$$

39. (a): As liquid 1 floats over liquid 2, so $\rho_1 < \rho_2$. As solid ball of density ρ_3 sinks in liquid 1 and floats over liquid 2, so $\rho_3 < \rho_2$ and $\rho_3 > \rho_1$.

Hence from above descriptions

$$\rho_1 < \rho_3 < \rho_2$$

40. (d): From Stefan's law, energy radiated by the sun per second,

$$E = \sigma AT^4 = \sigma \times 4\pi R^2 T^4$$

Power received per unit area at distance r from the sun,

$$I = \frac{E}{4\pi r^2} = \frac{\sigma \times 4\pi R^2 \times T^4}{4\pi r^2} = \frac{\sigma R^2 (t + 273)^4}{r^2}$$

41. (d): Only that circular orbit can be a stationary energy state which contains an integral number of de-Broglie wavelengths. For fifth orbit, we must have

$$2\pi r = 5\lambda$$

Hence option (d) is correct.

42. (b): Since work function of photoelectric emitter,

$$W_0 = h\nu_0 = \frac{hc}{\lambda_0} \quad \therefore W_0 \propto \frac{1}{\lambda_0}$$

$$\therefore \frac{W_1}{W_2} = \frac{\lambda_2}{\lambda_1} = \frac{600}{300} = 2:1$$

43. (b): The D.C. component of the output voltage is equal to the mean value of the sinusoidal signal.

$$V_{DC} = V_m = \frac{V_0}{\pi} = \frac{10}{\pi} \text{ V.}$$

44. (a): Limit of resolution of the eye,

$$d\theta = \frac{1.22\lambda}{D} \quad \dots(i)$$

Suppose the two dots separated by a distance d can be just resolved by the eye at a distance y , then

$$d\theta = \frac{d}{y} \quad \dots(ii)$$

From equations (i) and (ii)

$$\frac{1.22\lambda}{D} = \frac{d}{y}$$

$$\text{or } y = \frac{Dd}{1.22\lambda} = \frac{3 \times 10^{-3} \times 1 \times 10^{-3}}{1.22 \times 500 \times 10^{-9}} = 4.92 \text{ m} \approx 5 \text{ m}.$$

45. (b): Using mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \quad \dots(i)$$

Differentiating both sides with respect to t

$$-\frac{1}{v^2} \frac{dv}{dt} - \frac{1}{u^2} \frac{du}{dt} = 0$$

$$\text{or } \frac{dv}{dt} = -\frac{v^2}{u^2} \left(\frac{du}{dt} \right) \quad \dots(ii)$$

Here, $f = 20 \text{ cm}$, $u = -2.8 \text{ m} = -280 \text{ cm}$

\therefore From Equation (i)

$$\frac{1}{v} + \frac{1}{-280} = \frac{1}{20} \Rightarrow v = \frac{280}{15} \text{ cm}$$

$$\text{and } \frac{dv}{dt} = -\left(\frac{280}{15 \times 280} \right)^2 \times 15 = \frac{1}{15} \text{ m s}^{-1}$$

This is the required speed of image of second car.

46. (c): Time period of spring A, $T_1 = 2\pi \sqrt{\frac{M}{k_1}}$

where k_1 is spring constant of spring A.

Time period of spring B, $T_2 = 2\pi \sqrt{\frac{M}{k_2}}$

where k_2 is spring constant of spring B.

For series combination, spring constant

$$k_s = \frac{k_1 k_2}{k_1 + k_2}$$

$$\therefore T = 2\pi \sqrt{\frac{M}{k_s}} = 2\pi \sqrt{\frac{M(k_1 + k_2)}{k_1 k_2}}$$

$$\text{or } T^2 = \frac{4\pi^2 M}{k_1} + \frac{4\pi^2 M}{k_2} = T_1^2 + T_2^2$$

47. (c): Kinetic energy of SHM,

$$T = \frac{1}{2} m \omega^2 (A^2 - x^2) \quad \dots(i)$$

and potential energy of SHM,

$$V = \frac{1}{2} m \omega^2 x^2 \quad \dots(ii)$$

Dividing equation (i) by equation (ii),

$$\frac{T}{V} = \frac{(A^2 - x^2)}{x^2}$$

$$\begin{aligned} 48. (b): \vec{v} &= \vec{\omega} \times \vec{r} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 5 & -6 & 6 \\ 3 & -4 & 1 \end{vmatrix} \\ &= \hat{i}(-6 + 24) - \hat{j}(5 - 18) + \hat{k}(-20 + 18) \\ &= 18\hat{i} + 13\hat{j} - 2\hat{k} \end{aligned}$$

49. (c): Acceleration due to gravity on earth's surface

$$g = \frac{GM}{R^2} = \frac{G}{R^2} \times \frac{4}{3} \pi R^3 \rho = \frac{4\pi G R \rho}{3}$$

$$\text{or } \rho = \frac{3g}{4\pi G R} \quad \therefore \rho \propto g.$$

50. (d)



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Wave Optics

Light as a Wave and Wavefront

- General equation of displacement of light wave

$$y = a \sin \omega \left(t - \frac{x}{v} \right)$$

- In spherical wavefront

$$\text{Amplitude, } a \propto \frac{1}{r}, \text{ Intensity, } I \propto \frac{1}{r^2}$$

Young's Double Slit Experiment

- Path difference

$$\text{for bright fringe, } \Delta x = \frac{x d}{D} = n \lambda$$

$$\text{for dark fringe, } \Delta x = \frac{x d}{D} = (2n-1) \frac{\lambda}{2}$$

where $n = 1, 2, 3, \dots$

- Distance of n^{th} bright fringe from the centre of the screen,

$$x_n = \frac{n D}{d}, \quad n = 1, 2, 3, \dots$$

- Distance of n^{th} dark fringe from the centre of the screen,

$$x_n = (2n-1) \frac{D}{2d}$$

- Fringe width, $\beta = \frac{D \lambda}{d}$

- Wavelength of light used, $\lambda = \frac{\beta d}{D}$

- Angular position of n^{th} bright fringe

$$\theta_n = \frac{x_n}{D} = \frac{n \lambda}{d}$$

- Angular position of n^{th} dark fringe

$$\theta_n = \frac{x_n}{D} = (2n-1) \frac{\lambda}{2d}$$

- If the whole YDSE set up is taken in another medium then λ changes so β also changes e.g. in water

$$\lambda_w = \frac{\lambda_0}{\mu_w} \quad \text{and} \quad \beta = \frac{\beta_0}{\mu_w}$$

Interference of Light

- Resultant Intensity in the interference pattern of two monochromatic waves

$$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi$$

- Constructive interference

$$\text{If } \cos \phi = 1 \text{ or } \phi = 0, 2\pi, 4\pi, \dots$$

$$\text{then } I_R = I_{\max} = (\sqrt{I_1} + \sqrt{I_2})^2 = (a_1 + a_2)^2$$

- Destructive interference

$$\text{If } \cos \phi = -1 \text{ or } \phi = \pi, 3\pi, \dots$$

$$\text{then } I_R = I_{\min} = (\sqrt{I_1} - \sqrt{I_2})^2 = (a_1 - a_2)^2$$

- Fringe visibility

$$V = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$$

- At $I_1 = I_2 = I_0$

$$I_R = 2I_0(1 + \cos \phi) = 4I_0 \cos^2 \frac{\phi}{2}$$

- Intensity of light is proportional to the width of slit $I \propto w$

$$\frac{I_1}{I_2} = \frac{a_1}{a_2} = \frac{w_1}{w_2}$$

- Resultant amplitude

$$a_R = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos \phi}$$

Diffraction of Light at a Single Slit

- Fraunhofer diffraction

$$\text{for } n^{\text{th}} \text{ secondary minima } a \sin \theta = n \lambda$$

$$\text{for } n^{\text{th}} \text{ secondary maxima } a \sin \theta = (2n+1) \frac{\lambda}{2}$$

- Angular position of n^{th} minima

$$\theta_n = \frac{n \lambda}{a}$$

- Angular position of n^{th} secondary maxima

$$\theta_n = (2n+1) \frac{\lambda}{2a}$$

- Distance of n^{th} minima from the centre of screen

$$x_n = \frac{n D \lambda}{a}$$

- Distance of n^{th} secondary maxima from the centre of screen

$$x'_n = (2n+1) \frac{D \lambda}{2a}$$

$$\text{where } n = 1, 2, 3, \dots$$

- Width of central maxima

$$\beta_0 = 2\beta = \frac{2D \lambda}{a}$$

- Angular width of central maxima on either side

$$\theta = \pm \frac{\lambda}{a}$$

- Angular width of central maxima

$$2\theta = \frac{2\lambda}{a}$$

Diffraction of Light at Circular Aperture

- Angular spread of central maximum

$$\theta = \frac{1.22 \lambda}{d}$$

- Linear spread, $x = D \theta$

- Areal spread, $x^2 = (D \theta)^2$

- Fresnel distance $Z_F = \frac{d^2}{\lambda}$

- Size of fresnel zone $d_F = \sqrt{\lambda D}$

Where D is the distance at which the effect is considered and d is diameter of the aperture.

- Fresnel biprism fringe width obtained on screen

$$\beta = \frac{D \lambda}{d}$$

Diffraction Grating

- Grating element $= (a+b) = \frac{1 \text{ inch}}{N} = \frac{2.54 \text{ cm}}{N}$

where N is number of lines per inch of the grating plate

- For principal maximum in the grating spectra

$$(a+b) \sin \theta = n \lambda$$

Interference in Thin Films

- In reflected system of light

For maxima,

$$2\mu t \cos r = (2n+1) \frac{\lambda}{2}$$

For minima, $2\mu t \cos r = n \lambda$

- In transmitted system of light

For maxima, $2\mu t \cos r = n \lambda$

$$\text{For minima, } 2\mu t \cos r = (2n+1) \frac{\lambda}{2}$$

Where $n = 0, 1, 2, 3, \dots$

Polarization of Light

- Law of Malus

$$I = I_0 \cos^2 \theta$$

where θ is the angle between the plane of polariser and analyser.

- When a beam of unpolarised light is incident on the polariser then intensity

$$I = \frac{1}{2} \times \text{Intensity of unpolarised light } (I_0)$$

- Brewster's Law

$$\mu = \tan i_p \quad \text{and} \quad i_p + r_p = 90^\circ$$

where i_p is the polarising angle of incidence and r_p is corresponding angle of refraction.

Doppler Effect in Light

- Apparent frequency

When source (star) move towards the observer with velocity v ,

$$v' = v / \left(1 - \frac{v}{c} \right), v' > v$$

When source move away from the observer with velocity v ,

$$v' = v / \left(1 + \frac{v}{c} \right), v' < v$$

- Doppler shift $\Delta v = v' - v = \pm \frac{v}{c} v$

- Blue shift $\Delta \lambda = \lambda' - \lambda = -\frac{v}{c} \lambda$

where, $\lambda' < \lambda$

- Red shift $\Delta \lambda = \lambda' - \lambda = +\frac{v}{c} \lambda$

where, $\lambda' > \lambda$

- Velocity of rocket / aeroplane / submarine, which are detected by reflected em waves

$$v = \pm \frac{1}{2} \frac{\Delta v}{v} c$$

$$= \pm \frac{1}{2} \frac{\Delta \lambda}{\lambda} c$$

Resolving power of Optical Instruments

- Resolving power of a telescope

$$= \frac{1}{d \theta} = \frac{D}{1.22 \lambda}$$

where D is diameter of the objective lens

- Resolving power of microscope

$$= \frac{1}{d} = \frac{2 \mu \sin \theta}{\lambda}$$

- Reciprocal of resolving power is known as limit of resolution

Displacement of Interference fringes

- When a thin transparent sheet of thickness t and refractive index μ is inserted in one of the interfering beams path difference introduced

$$\Delta x = (\mu - 1)t$$

- Displacement of the central bright fringe,

$$\Delta x = \frac{\beta}{\lambda} (\mu - 1)t = \frac{D}{d} (\mu - 1)t$$

PRACTICE PAPER 2Q14

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Exam on
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- Two drops of equal radius coalesce to form a bigger drop. What is ratio of surface energy of bigger drop to smaller one?
(a) $2^{1/2} : 1$ (b) $1 : 1$
(c) $2^{2/3} : 1$ (d) $1 : 2^{1/3}$
- 1 g of water at atmospheric pressure has volume of 1 cm^3 and when boiled it becomes 1681 cm^3 of steam. The heat of vaporisation of water is 540 cal g^{-1} . Then the change in its internal energy in this process is
(a) 540 cal (b) 500 cal
(c) 1681 cal (d) 480 cal
- A horizontal platform with an object placed on it is executing S.H.M. in the vertical direction. The amplitude of oscillation is $3.92 \times 10^{-3} \text{ m}$. What must be the least period of these oscillations, so that the object is not detached from the platform?
(a) 0.1256 s (b) 0.1356 s
(c) 0.1456 s (d) 0.1556 s
- A $4 \mu\text{F}$ capacitor is charged by a 200 V supply. It is then disconnected from the supply and is connected to another uncharged $2 \mu\text{F}$ capacitor. The energy lost in the process is
(a) $3 \times 10^{-2} \text{ J}$ (b) $3 \times 10^2 \text{ J}$
(c) $2.6 \times 10^{-2} \text{ J}$ (d) $2.8 \times 10^2 \text{ J}$
- A wire of length 15 cm and radius 0.25 mm connected in the left gap of a meter bridge balances a 10Ω resistance in the right gap at a point which divides the bridge wire in the ratio 3 : 2. The specific resistance of the wire is
(a) $2.0 \times 10^{-7} \Omega \text{ m}$ (b) $2.0 \times 10^{-8} \Omega \text{ m}$
(c) $2.0 \times 10^{-6} \Omega \text{ m}$ (d) $2.0 \times 10^{-5} \Omega \text{ m}$
- Two concentric coplanar circular loops of radii r_1 and r_2 carry currents I_1 and I_2 respectively in opposite directions (one clockwise and other anticlockwise). The magnetic induction at the centre of the loops is half due to I_1 alone. If $r_2 = 2r_1$, the value of I_2/I_1 is
(a) 2 (b) 1/2 (c) 1/4 (d) 1
- A magnetic flux of $500 \mu\text{Wb}$ passing through a 200 turns coil is reversed in $20 \times 10^{-3} \text{ s}$. The average e.m.f. induced in the coil is
(a) 2.5 V (b) 5.0 V
(c) 7.5 V (d) 10.0 V
- A particle covers 4 m, 5 m, 6 m and 7 m in 3rd, 4th, 5th and 6th second respectively. The particles start
(a) with an initial non-zero velocity and moves with uniform acceleration.
(b) from rest and moves with uniform velocity.
(c) with an initial velocity and moves with uniform velocity.
(d) from rest and moves with uniform acceleration.
- A block of mass 5 kg, resting on a horizontal surface, is connected by a chord, passing over a light frictionless pulley to a hanging block of mass 5 kg. The coefficient of kinetic friction between the block and the surface is 0.5. Tension in the chord is (Take $g = 9.8 \text{ m s}^{-2}$)
(a) 49 N (b) 36 N
(c) 36.75 N (d) 2.45 N
- A spring of spring constant $5 \times 10^3 \text{ N m}^{-1}$ is stretched initially by 5 cm from the unstretched position. Then the work required to stretch it further by another 5 cm is
(a) 12.50 N m (b) 18.75 N m
(c) 25.00 N m (d) 6.25 N m
- An isolated particle of mass m is moving in a horizontal plane (x - y) along the x -axis, at a certain height above the ground. It suddenly explodes into two fragments of masses $m/4$ and $3m/4$. An instant later, the smaller fragment is at $y = +15 \text{ cm}$. the larger fragment at this instant is at
(a) $y = -5 \text{ cm}$ (b) $y = +20 \text{ cm}$
(c) $y = +5 \text{ cm}$ (d) $y = -20 \text{ cm}$
- If a spring extends by x on loading, then the energy stored in the spring is (if T is the tension and k is the force constant of the spring)

- (a) $\frac{T^2}{2x}$ (b) $\frac{T^2}{2k}$
 (c) $\frac{2k}{T^2}$ (d) $\frac{2T^2}{k}$

13. A stick is thrown in the air and lands on the ground at some distance from the thrower. The centre of mass of the stick will move along a parabolic path
 (a) in all cases
 (b) only if the stick is uniform
 (c) only if the stick has linear motion but no rotational motion
 (d) only if the stick has a shape such that its centre of mass is located at some point on it and not outside it
14. A particle of mass m is tied to a light string and rotated with a speed v along a circular path of radius r . If T = tension in the string and mg = gravitational force on the particle then the actual forces acting on the particle are
 (a) mg and T only
 (b) mg , T and an additional force of mv^2/r directed inwards
 (c) mg , T and an additional force of mv^2/r directed outwards
 (d) only a force mv^2/r directed outwards
15. A U-tube containing a liquid moves with a horizontal acceleration a along a direction joining the two vertical limbs. The separation between these limbs is d . The difference in their liquid levels is
 (a) ad/g (b) $2da/g$
 (c) $da/2g$ (d) $d\tan(a/g)$
16. An electric bulb is designed to draw P_0 power at V_0 voltage. If the voltage is V , it draws P power. Then ρ is given by
 (a) $\frac{V_0}{V} P_0$ (b) $\frac{V}{V_0} P_0$
 (c) $\left(\frac{V}{V_0}\right)^2 P_0$ (d) $\left(\frac{V_0}{V}\right)^2 P_0$
17. The distance between the circular plates of a parallel plate condenser 40 mm in diameter, in order to have same capacity as a sphere of radius 1 m is
 (a) 0.01 mm (b) 0.1 mm
 (c) 1.0 mm (d) 10 mm
18. A metal rod of length 2 m is rotating with an angular velocity of 100 rad s^{-1} in a plane perpendicular to a uniform magnetic field of

0.3 T. the potential difference between the ends of the rod is

- (a) 30 V (b) 40 V
 (c) 60 V (d) 600 V

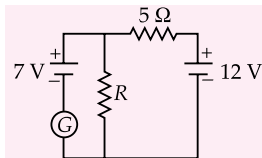
19. Current through an AC series L - C - R circuit is 2 A if operated at resonant frequency and 1 A if operated at 50% less than resonant frequency. The current (in A) if the frequency is 100 % more than the resonant frequency is
 (a) $\sqrt{2}$ (b) 1
 (c) $\sqrt{3}$ (d) Data insufficient
20. A plano-convex lens of curvature of 30 cm and refractive index 1.5 produces a real image of an object kept 90 cm from it. What is the magnification?
 (a) 4 (b) 0.5
 (c) 1.5 (d) 2
21. Two slits are separated by a distance of 0.5 mm and illuminated with light of wavelength $\lambda = 6000 \text{ \AA}$. If the screen is placed at 2.5 m from the slits. The distance of the third bright image from the centre will be
 (a) 1.5 mm (b) 3 mm
 (c) 6 mm (d) 9 mm
22. The torque required to hold a small circular coil of 10 turns, $2 \times 10^{-4} \text{ m}^2$ area and carrying 0.5 A current in the middle of a long solenoid of $10^3 \text{ turns m}^{-1}$ carrying 3 A current, with its axis perpendicular to the axis of the solenoid, is
 (a) $12\pi \times 10^{-7} \text{ N m}$ (b) $6\pi \times 10^{-7} \text{ N m}$
 (c) $4\pi \times 10^{-7} \text{ N m}$ (d) $2\pi \times 10^{-7} \text{ N m}$
23. A convex lens forms an image of an object placed 20 cm away from it at a distance of 20 cm on the other side of the lens. If the object is moved 5 cm towards the lens, the image will move
 (a) 5 cm towards the lens
 (b) 5 cm away from the lens
 (c) 10 cm towards the lens
 (d) 10 cm away from the lens
24. A sample of an element weighs 10.38 g. If half-life of element is 3.8 days, then after 19 days, how much quantity of element will remain?
 (a) 0.151 g (b) 0.32 g
 (c) 1.51 g (d) 0.16 g
25. The work done in increasing the size of a rectangular soap film with dimensions $8 \text{ cm} \times 3.75 \text{ cm}$ to $10 \text{ cm} \times 6 \text{ cm}$ is $2 \times 10^{-4} \text{ J}$. The surface tension of the film in N m^{-1} is
 (a) 1.65×10^{-2} (b) 3.3×10^{-2}
 (c) 6.6×10^{-2} (d) 8.25×10^{-2}

26. If the heat 110 J is added to a gaseous system and it acquires internal energy of 40 J, then the amount of internal work done is
(a) 40 J (b) 70 J (c) 150 J (d) 110 J

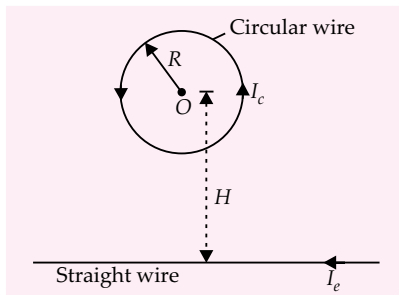
27. The dimensions of $\frac{l}{KA}$ is

(Here, l is the length of rod, K is the thermal conductivity of rod and A is area of cross-section of rod)

- (a) $[ML^2T^{-3}K^{-1}]$ (b) $[M^{-1}L^{-2}T^3K]$
(c) $[ML^2T^{-3}K^{-2}]$ (d) $[MLT^{-3}K^{-1}]$
28. A body starting from rest moves with constant acceleration. The ratio of distance covered by the body during the 5th s to that covered in 5 s is
(a) $\frac{9}{25}$ (b) $\frac{3}{25}$ (c) $\frac{25}{9}$ (d) $\frac{1}{25}$
29. Same force acts on two bodies of different masses 3 kg and 5 kg initially at rest. The ratio of times required to acquire same final velocity is
(a) 5 : 3 (b) 25 : 9 (c) 9 : 25 (d) 3 : 5
30. For what value of R will the current in galvanometer be zero?



- (a) 1 Ω (b) 2 Ω (c) 5 Ω (d) 7 Ω
31. A small object placed on a rotating horizontal turn table just slips when it is placed at a distance of 4 cm from the axis of rotation. If the angular velocity of the turn-table is doubled the object slips when its distance from the axis of rotation is
(a) 1 cm (b) 2 cm (c) 4 cm (d) 8 cm
32. Circular loop of a wire and a long straight wire carry currents I_c and I_e respectively as shown in figure. Assuming that these are placed in the same plane, the magnetic fields will be zero at the centre of the loop when separation H is



- (a) $\frac{I_e R}{I_c \pi}$ (b) $\frac{I_c R}{I_e \pi}$ (c) $\frac{\pi I_e}{I_c R}$ (d) $\frac{\pi I_c}{I_e R}$

33. A rod of length 1.4 m and negligible mass has two masses of 0.3 kg and 0.7 kg tied to its two ends. Find the location of the point on this rod, where the rotational energy is minimum, when the rod is rotated about the point.

- (a) 0.98 m from 0.3 kg (b) 0.98 m from 0.7 kg
(c) 0.7 m from 0.3 kg (d) 0.7 m from 0.7 kg
34. A charged cloud system produces an electric field in the air near the earth's surface. A particle of charge -2×10^{-9} C is acted on by a downward electrostatic force of 3×10^{-6} N when placed in this field. The gravitational and electrostatic force, respectively, exerted on a proton placed in this field are
(a) 1.64×10^{-26} N, 2.4×10^{-16} N
(b) 1.64×10^{-26} N, 1.5×10^3 N
(c) 1.56×10^{-18} N, 2.4×10^{-16} N
(d) 1.5×10^3 N, 2.4×10^{-16} N

35. An inductor of inductance 10 H connected in series with a resistance $R = 6 \Omega$. A 12 V battery is connected for a long time. When the circuit is switched off, the induced emf in inductor, if current reduces to zero in 10 ms, is
(a) 1000 V (b) 2000 V
(c) 3000 V (d) 4000 V

36. If 2 moles of an ideal monoatomic gas at temperature T_0 is mixed with 4 moles of another ideal monoatomic gas at temperature $2T_0$, then the temperature of the mixture is
(a) $(5/3)T_0$ (b) $(3/2)T_0$
(c) $(4/3)T_0$ (d) $(5/4)T_0$

37. The displacement of a particle is represented by the equation : $y = 3 \cos\left(\frac{\pi}{4} - 2\omega t\right)$.

The motion of the particle is

- (a) simple harmonic with period $2\pi/\omega$
(b) simple harmonic with period π/ω
(c) periodic but not simple harmonic
(d) non-periodic
38. An engine has an efficiency of 1/6. When the temperature of the sink is reduced by 62°C , its efficiency is doubled. The temperature of the source is
(a) 37°C (b) 62°C (c) 99°C (d) 124°C

39. The retarding potential necessary to stop the emission of photoelectron, when a target material of work function 1.24 eV is irradiated with light of wavelength 4.36×10^{-7} m is
(a) 0.36 V (b) 1.60 V
(c) 2.84 V (d) 4.08 V

40. The transfer ratio β of a transistor is 50. The input resistance of the transistor when used in the common emitter configuration is $1\text{ k}\Omega$. The peak value of the collector AC current for a peak value of AC input voltage of 0.01 V is
- (a) $100\text{ }\mu\text{A}$ (b) $0.01\text{ }\mu\text{A}$
(c) $0.25\text{ }\mu\text{A}$ (d) $500\text{ }\mu\text{A}$

Directions : In the following questions (41-60), a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as

- (a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

41. **Assertion :** If a pendulum falls freely, then its time period becomes infinite.
Reason : A freely falling body has acceleration equal to g .
42. **Assertion :** A needle placed carefully on surface of water may float whereas a ball of the same material will always sink.
Reason : The buoyancy of an object depends both on the material and the shape of the object.
43. **Assertion :** It is easier to pull a heavy object than to push it on a level ground.
Reason : The magnitude of frictional force depends on the nature of the two surfaces in contact.
44. **Assertion :** If polar ice melts, days will be longer.
Reason : Moment of inertia decreases and thus angular velocity increases.
45. **Assertion :** Two particles moving in the same direction do not lose all their energy in a completely inelastic collision.
Reason : Principle of conservation of momentum holds true for all kinds of collision.
46. **Assertion :** In a simple battery circuit the point of lowest potential is positive terminal of the battery.
Reason : The current flows towards the point of the higher potential as it flows in such a circuit from the negative to the positive terminal.
47. **Assertion :** When a magnet is brought near iron nails, only translatory force acts on it.
Reason : The field due to a magnet is generally uniform.
48. **Assertion :** The presence of large magnetic flux through a coil maintains a current in the coil, if

the circuit is continuous.

Reason : Only a change in magnetic flux will maintain an induced current in the coil.

49. **Assertion :** Bigger drops of liquid resist deforming forces better than the smaller drops.
Reason : Excess pressure inside the drop is directly proportional to its radius.
50. **Assertion :** The internal energy of a real gas is a function of both, temperature and volume.
Reason : Internal K.E. depends on temperature and internal P.E. depends on volume.
51. **Assertion :** If a hole were drilled through the centre of earth and a ball dropped into the hole at one end, it will not get out of other end of the hole.
Reason : It should come out of the other end normally.
52. **Assertion :** A particle is projected at an angle θ ($< 90^\circ$) to horizontal, with a velocity u . When particle strikes the ground its speed is again u .
Reason : Velocity along horizontal direction remains same but velocity along vertical direction is changed. When particle strikes the ground then magnitude of final vertical velocity is equal to magnitude of initial vertical velocity.
53. **Assertion :** A man who falls from a height on a cement floor receives more injury than when he falls from the same height on a heap of sand.
Reason : The impulse applied by a cement floor is less than the impulse by a sand floor.
54. **Assertion :** According to the law of conservation of mechanical energy change in potential energy is equal and opposite to the change in kinetic energy.
Reason : Mechanical energy is not a conserved quantity.
55. **Assertion :** At a fixed temperature, silicon will have a minimum conductivity when it has a smaller acceptor doping.
Reason : The conductivity of an intrinsic semiconductor is slightly higher than that of a lightly doped p -type.
56. **Assertion :** The ratio of time taken for light emission from an atom to that for release of nuclear energy in fission is $1 : 100$.
Reason : Time taken of the light emission from an atom is of the order of 10^{-8} s .

57. Assertion : The de Broglie equation has significance for any microscopic or sub-microscopic particle.

Reason : The de Broglie wavelength is inversely proportional to the mass of the object if velocity is constant.

58. Assertion : In front of a concave mirror a point object is placed between focus and centre of curvature. If a glass slab is placed between object and mirror then image from mirror may become virtual.

Reason : Glass slab always makes a virtual image of a real object.

59. Assertion : In Young's double slit experiment ratio $\frac{I_{\max}}{I_{\min}}$ is infinite.

Reason : If width of any one of the slits is slightly increased, then this ratio will decrease.

60. Assertion : If high pressure is applied on a radioactive substance rate of radioactivity does not change.

Reason : Radioactivity is a nuclear process.

SOLUTIONS

1. (d): Volume of bigger drop = Volume of two smaller drops

$$\therefore \frac{4}{3}\pi R'^3 = 2 \times \frac{4}{3}\pi R^3$$

$$\Rightarrow R' = 2^{1/3} R$$

Initial surface energy,

$$U_1 = 8\pi R^2\sigma$$

Final surface energy,

$$U_2 = 4\pi R'^2\sigma = 4\pi \times 2^{2/3} R^2\sigma$$

$$\therefore \frac{U_2}{U_1} = \frac{4\pi\sigma \times 2^{2/3} R^2}{8\pi R^2\sigma} = 1 : 2^{1/3}$$

2. (b): Here, $m = 1 \text{ g}$, $V_1 = 1 \text{ cm}^3$

$$V_2 = 1681 \text{ cm}^3$$

$$L = 540 \text{ cal g}^{-1}$$

$$P = 1 \text{ atm} = 10^5 \text{ N m}^{-2}$$

\therefore Latent heat of vaporisation

$$Q = mL = 1 \times 540 = 540 \text{ cal}$$

$$\Delta V = V_2 - V_1 = 1681 - 1 = 1680 \text{ cm}^3$$

$$= 1680 \times 10^{-6} \text{ m}^3$$

$$\text{and } W = P\Delta V = 10^5 \times 1680 \times 10^{-6}$$

$$= 168 \text{ J} = \frac{168}{4.2} \text{ cal} = 40 \text{ cal.}$$

\therefore Change in internal energy.

$$\Delta U = Q - W = 540 - 40 = 500 \text{ cal}$$

3. (a): For object not to get detached from the platform,

$$a_{\max} \leq g \text{ or } \omega^2 A \leq g$$

$$\text{or } \left(\frac{2\pi}{T}\right)^2 A \leq g \text{ or } T_{\min} = 2\pi \sqrt{\frac{A}{g}} = 2\pi \sqrt{\frac{3.92 \times 10^{-3}}{9.8}} \\ = 2\pi \times 2 \times 10^{-2} = 0.1256 \text{ s}$$

4. (c): Here, $C_1 = 4 \mu\text{F}$, $V_1 = 200 \text{ V}$,

$$C_2 = 2 \mu\text{F}.$$

Initial energy stored in C_1 ,

$$E_1 = \frac{1}{2} C_1 V_1^2 = \frac{1}{2} \times (4 \times 10^{-6}) (200)^2 \\ = 8 \times 10^{-2} \text{ J}$$

and charge on capacitor C_1

$$q_1 = C_1 V_1 = 4 \times 200 = 800 \mu\text{C}.$$

After connecting of C_1 to C_2 , common potential,

$$V_2 = \frac{q_1}{C_1 + C_2} = \frac{C_1 V_1}{C_1 + C_2} = \frac{800}{4 + 2} = \frac{400}{3} \text{ V}$$

$$\therefore \text{ Final energy, } E_2 = \frac{1}{2} (C_1 + C_2) V_2^2$$

$$= \frac{1}{2} \times 6 \times 10^{-6} \times \left(\frac{400}{3}\right)^2 = 5.33 \times 10^{-2} \text{ J}$$

$$\therefore \text{ Loss of energy } = E_1 - E_2$$

$$= 8 \times 10^{-2} - 5.33 \times 10^{-2} = 2.67 \times 10^{-2} \text{ J}$$

5. (d): Here, $l = 15 \text{ cm} = 0.15 \text{ m}$, $r = 0.25 \text{ mm} = 0.25 \times 10^{-3} \text{ m}$

$$S = 10 \Omega, \frac{L}{100 - L} = \frac{3}{2}.$$

For meter bridge balance,

$$\frac{R}{S} = \frac{L}{100 - L}$$

$$\therefore \frac{R}{10} = \frac{3}{2} \Rightarrow R = \frac{10 \times 3}{2} = 15 \Omega$$

\therefore Specific resistance of the wire,

$$\rho = \frac{R \cdot \pi r^2}{l} = R \times 3.14 \times \frac{(0.25 \times 10^{-3})^2}{0.15}$$

$$= 15 \times 3.14 \times \frac{625 \times 10^{-10}}{15 \times 10^{-2}} \approx 2 \times 10^{-5} \Omega \text{ m}$$

6. (d): Fields at the centre due to both circular loops of

$$\text{radii } r_1 \text{ and } r_2 \text{ is } B_1 = \frac{\mu_0}{4\pi} \frac{2\pi I_1}{r_1} \text{ and } B_2 = \frac{\mu_0}{4\pi} \frac{2\pi I_2}{r_2}$$

Here \vec{B}_1 and \vec{B}_2 are in opposite direction. Therefore resultant magnetic field induction is

$$B = B_1 - B_2 = \frac{\mu_0 I_1}{2r_1} - \frac{\mu_0 I_2}{2r_2}$$

$$= \frac{\mu_0 I_1}{2r_1} - \frac{\mu_0 I_2}{2 \times 2r_1} = \frac{\mu_0}{4r_1} (2I_1 - I_2) \quad [\because r_2 = 2r_1]$$

As per question, $B = B_1/2$

$$\Rightarrow \frac{\mu_0}{4r_1} (2I_1 - I_2) = \frac{1}{2} \times \frac{\mu_0 I_1}{2r_1}$$

$$\text{or } 2I_1 - I_2 = I_1 \text{ or } I_1 = I_2 \Rightarrow \frac{I_2}{I_1} = 1$$

7. (d): Here, $\Delta\phi = \phi_2 - \phi_1 = 200 [500 - (-500)] \mu\text{Wb}$
 $= 200000 \mu\text{Wb}$
 $= 0.2 \text{ Wb}$

$$\Delta t = 20 \times 10^{-3} \text{ s}$$

\therefore emf induced in the coil,

$$\varepsilon = \frac{d\phi}{dt} = \frac{0.2}{20 \times 10^{-3}} = 10 \text{ V}$$

8. (a): Since distance covered in n^{th} second,

$$S = u + \frac{a}{2}(2n - 1)$$

$$\therefore 4 = u + \frac{a}{2}(2 \times 3 - 1) \text{ or } 4 = u + \frac{5a}{2}, \quad \dots(i)$$

$$5 = u + \frac{a}{2}(2 \times 4 - 1) \text{ or } 5 = u + \frac{7a}{2} \quad \dots(ii)$$

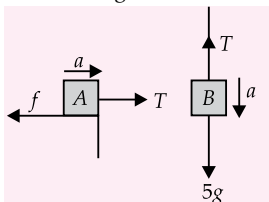
Subtracting equation (i) from (ii)

$$1 = \frac{7a}{2} - \frac{5a}{2} = \frac{2a}{2} = a \Rightarrow a = 1 \text{ m s}^{-2}.$$

$$\text{Again, } 4 = u + \frac{5}{2} \text{ or } u = 4 - \frac{5}{2} = 1.5 \text{ m s}^{-1}$$

So, the initial velocity is non-zero and acceleration is uniform.

9. (c): Refer to the free body diagram of block B
 $5g - T = 5a \text{ or } T = 5g - 5a \quad \dots(i)$



Refer to the free body diagram of block A

$$T - f = 5a$$

$$\text{or } 5g - 5a - 0.5 \times 5 \times g = 5a \quad (\text{using (i)})$$

$$\text{or } 10a = 2.5g = 2.5 \times 9.8$$

$$\text{or } a = 0.25 \times 9.8 \text{ m s}^{-2} = 2.45 \text{ m s}^{-2} \quad \dots(ii)$$

Again from Equations (i) and (ii),

$$T = (5 \times 9.8 - 5 \times 2.45) \text{ N}$$

$$= (49 - 12.25) \text{ N} = 36.75 \text{ N}$$

10. (b): Potential energy stored in spring when it stretched by 5 cm is

$$U_1 = \frac{1}{2} kx_1^2 = \frac{1}{2} \times 5 \times 10^3 \times (5 \times 10^{-2})^2 = 6.25 \text{ J}$$

Potential energy stored in spring when it is further

$$\text{stretched by 5 cm is } U_2 = \frac{1}{2} k(x_1 + x_2)^2$$

$$= \frac{1}{2} \times 5 \times 10^3 \times (5 \times 10^{-2} + 5 \times 10^{-2})^2 = 25 \text{ J}$$

$$\therefore \text{Work required to stretch further} = U_2 - U_1 = 25 - 6.25 = 18.75 \text{ J} = 18.75 \text{ N m}$$

11. (a): Since there is no external force acting on the particle, hence

$$y_{\text{CM}} = \frac{m_1 y_1 + m_2 y_2}{m_1 + m_2} = 0,$$

$$\therefore \left(\frac{m}{4}\right) \times (+15) + \left(\frac{3m}{4}\right) (y_2) = 0$$

$$\Rightarrow y_2 = -5 \text{ cm}$$

12. (d): In equilibrium, $T = mg$

\therefore Work done in extending = energy stored in the spring

$$\Rightarrow mgx = \frac{1}{2} kx^2$$

$$\text{or } x = \frac{2mg}{k} = \frac{2T}{k}$$

$$\therefore \text{Energy stored} = mgx = Tx$$

$$= T \times \frac{2T}{k} = \frac{2T^2}{k}$$

13. (a): We may consider the entire mass of the stick to be concentrated as a point mass at the centre of mass of the stick. As the centre of mass moves as a projectile, it will move along a parabolic path.

14. (a): The force mv^2/r directed outwards, called centrifugal force, is not a real force but a pseudoforce.

15. (a): Let A = area of cross-section of the tube,
 ρ = density of the liquid.

Consider the section AB of the tube.

Mass of the liquid in $AB = dA\rho$.

Pressures at A and B

$$= h_2 \rho g \text{ and } h_1 \rho g.$$

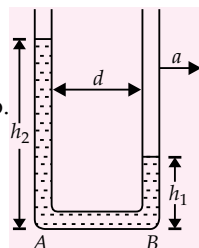
Net force to the right on AB

$$= (h_2 \rho g - h_1 \rho g) A.$$

$$\therefore (h_2 - h_1) \rho g A = (dA\rho) a$$

$$\text{or } (h_2 - h_1) g = da$$

$$\text{or } h_2 - h_1 = ad/g.$$



16. (c): Let R = resistance of the bulb.

$$\therefore P_0 = \frac{V_0^2}{R}$$

$$\Rightarrow R = \frac{V_0^2}{P_0}$$

$$\text{Now, } P = \frac{V^2}{R} = \frac{V^2}{(V_0^2/P_0)} = \left(\frac{V}{V_0}\right)^2 P_0$$

17. (b): According to question,

Capacity of spherical condenser = Capacity of parallel plate capacitor

$$\therefore 4\pi\epsilon_0 r = \frac{\epsilon_0 A}{d}$$

$$\therefore d = \frac{A}{4\pi r} = \frac{\pi R^2}{4\pi r} = \frac{\pi(20 \times 10^{-3})^2}{4\pi \times 1} = 0.1 \text{ mm}$$

18. (c): Induced emf, when rod rotates in a vertical plane perpendicular to magnetic field

$$\epsilon = \frac{1}{2} B l^2 \omega$$

Here, $B = 0.3 \text{ T}$

$$l = 2 \text{ m and } \omega = 100 \text{ rad s}^{-1}$$

$$= \frac{1}{2} \times 0.3 \times (2)^2 \times 100 = 60 \text{ V}$$

19. (b): At resonance, $X_C = X_L$
If ω is made 50% less than resonant frequency i.e. half

$$\text{then } X'_C = 2X_C \text{ and } X'_L = \frac{X_L}{2}$$

$$\left(\text{as } X_C \propto \frac{1}{\omega} \text{ and } X_L \propto \omega \right)$$

If ω is made 100% more than the resonant frequency i.e. two times,

$$\text{then, } X'_C = \frac{X_C}{2} \text{ and } X'_L = 2X_L$$

i.e., value of Z will remain unchanged, so, current should be 1 A.

20. (d): From lense maker's formula

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

Here for plano-convex lens

$$R_1 = \infty, R_2 = -30 \text{ cm}$$

$$u = -90 \text{ cm}, \mu = 1.5$$

$$\frac{1}{v} - \frac{1}{-90} = \frac{1}{f} = (1.5 - 1) \left(\frac{1}{30} \right) = \frac{1}{60}$$

$$\therefore v = 180 \text{ cm}$$

$$\text{Now, } |m| = \left| \frac{v}{u} \right| = \frac{180}{90} = 2.$$

21. (d): Distance of n^{th} bright fringe from the centre,

$$x_n = \frac{nD\lambda}{d}$$

$$\text{So, } x_3 = \frac{3 \times 2.5 \times 6000 \times 10^{-10}}{0.5 \times 10^{-3}} = 9 \times 10^{-3} \text{ m} = 9 \text{ mm}$$

22. (a): Magnetic dipole moment of current loop is
 $M = NIA = 10 \times 0.5 \times 2 \times 10^{-4} = 10^{-3} \text{ A m}^2$
Magnetic field due to the carrying current solenoid

$$B = \mu_0 nI = 4\pi \times 10^{-7} \times 10^3 \times 3 = 12\pi \times 10^{-4} \text{ T}$$

$$\therefore \text{Torque, } \tau = MB \sin \theta = 10^{-3} \times 12\pi \times 10^{-4} \times \sin 90^\circ = 12\pi \times 10^{-7} \text{ N m}$$

23. (d): Clearly, in the first arrangement, $2f = 20 \text{ cm}$ or $f = 10 \text{ cm}$

$$\text{Now, } u = -15 \text{ cm, } f = 10 \text{ cm}$$

$$\Rightarrow \frac{1}{v} - \frac{1}{-15} = \frac{1}{10}$$

$$\text{or } \frac{1}{v} + \frac{1}{15} = \frac{1}{10} \text{ or } \frac{1}{v} = \frac{1}{10} - \frac{1}{15}$$

$$\text{or } \frac{1}{v} = \frac{3-2}{30} = \frac{1}{30} \text{ or } v = 30 \text{ cm}$$

\therefore The change in image distance = $30 - 20 = 10 \text{ cm}$ (away from the lens)

$$24. (b): \text{As } \frac{N}{N_0} = \left(\frac{1}{2} \right)^{t/T} = \frac{m}{m_0}$$

$$\therefore \frac{m}{10.38} = \left(\frac{1}{2} \right)^{19/3.8}$$

$$\Rightarrow m = 10.38 \times \left(\frac{1}{2} \right)^5 = \frac{10.38}{32} = 0.32 \text{ g}$$

25. (b): Change in surface energy = $2 \times 10^{-4} \text{ J}$

$$\Delta A = 10 \times 6 - 8 \times 3.75 = 60 - 30$$

$$= 30 \text{ cm}^2 = 30 \times 10^{-4} \text{ m}^2$$

$$\text{Work done } W = T \times 2 \times 30 \times 10^{-4}$$

$$\Rightarrow T = 3.3 \times 10^{-2} \text{ N m}^{-1}$$

26. (b): Here, $dQ = 110 \text{ J}$, $dU = 40 \text{ J}$

$$\text{Since } dQ = dU + dW$$

$$\therefore dW = dQ - dU = 110 - 40 = 70 \text{ J}$$

27. (b): Since rate of heat flow $\frac{dQ}{dt} = \frac{KA\Delta T}{l}$

$$\therefore \frac{l}{KA} = \left[\frac{dT}{(dQ/dt)} \right] = \left[\frac{\text{kelvin} \times \text{second}}{\text{joule}} \right]$$

$$= \frac{[K][T]}{[ML^2T^{-2}]} = [M^{-1}L^{-2}T^3K]$$

28. (a): Distance covered in 5^{th} s is

$$D_5 = 0 + \frac{a}{2} (2 \times 5 - 1) = \frac{9a}{2} \quad \dots(i)$$

Distance covered in 5 s is

$$S_5 = 0 + \frac{1}{2} \times a \times 5^2 = \frac{25a}{2} \quad \dots(ii)$$

Dividing equation (i) by (ii)

$$\frac{D_5}{S_5} = \frac{9}{25}$$

29. (d): $m_1 = 3 \text{ kg}$, $m_2 = 5 \text{ kg}$, $u_1 = u_2 = 0$ and $v_1 = v_2 = v$

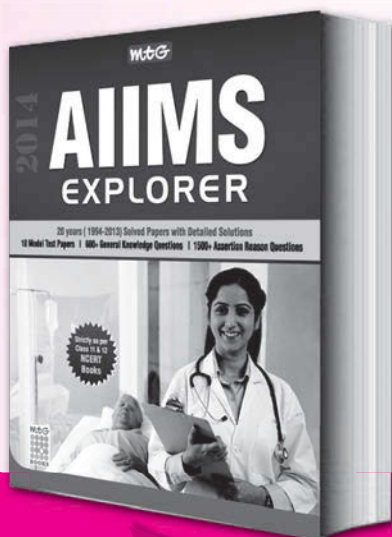
As $F_1 = F_2$ (Same force is acting on the bodies)

$$\therefore m_1 \left(\frac{v_1 - u_1}{t_1} \right) = m_2 \left(\frac{v_2 - u_2}{t_2} \right)$$

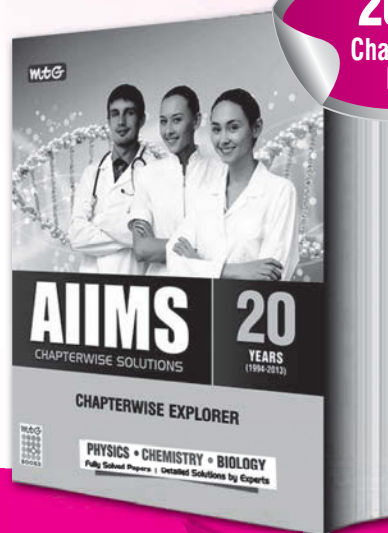


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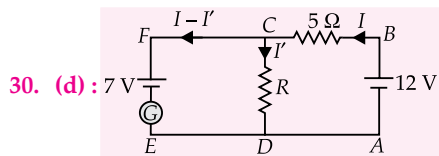
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$$\Rightarrow 3 \frac{(v-0)}{t_1} = 5 \frac{(v-0)}{t_2}, \quad \frac{3v}{t_1} = \frac{5v}{t_2} \text{ or } \frac{t_1}{t_2} = \frac{3v}{5v}$$

$$\therefore t_1 : t_2 = 3 : 5$$



Applying Kirchhoff's second law to the closed loop ABCDA, we get

$$-5I - I'R + 12 = 0 \quad \dots(i)$$

Again, applying Kirchhoff's second law to the closed loop CDEFC, we get

$$-I'R + 7 = 0 \quad \dots(ii)$$

Since current in galvanometer is zero

$$\therefore I = I' \quad \dots(iii)$$

Solving equations (i), (ii), and (iii) we get

$$R = 7 \Omega$$

31. (a): The object will slip if
centripetal force \geq force of friction

$$\therefore m\omega^2 \geq \mu mg$$

$$\Rightarrow r\omega^2 \geq \mu g$$

$$r\omega^2 = \text{constant}$$

$$\therefore \frac{r_1}{r_2} = \left(\frac{\omega_2}{\omega_1} \right)^2$$

$$\frac{4 \text{ cm}}{r_2} = \left(\frac{2\omega}{\omega} \right)^2 \text{ or } r_2 = 1 \text{ cm}$$

32. (a): Magnetic field at the centre O of the circular

$$\text{current loop is } B_1 = \frac{\mu_0}{4\pi} \frac{2\pi I_c}{R}$$

Magnetic field at the centre O of the circular loop due to current through long straight wire is

$$B_2 = \frac{\mu_0}{4\pi} \frac{2I_e}{H}$$

As the resultant magnetic field at O is zero (given), hence B_1 and B_2 must be equal in magnitude and opposite in direction. So

$$\frac{\mu_0}{4\pi} \frac{2\pi I_c}{R} = \frac{\mu_0}{4\pi} \frac{2I_e}{H} \text{ or } H = \frac{I_e R}{\pi I_c}$$

33. (a): Rotational energy is minimum when moment of inertia is minimum about the axis of rotation. If this point is at distance x from 0.3 kg mass, then

$$I = 0.3x^2 + 0.7(1.4 - x)^2$$

$$\text{Now, for minima. } \frac{dI}{dx} = 0$$

$$\text{or } 0.6x + 1.4(1.4 - x)(-1) = 0$$

$$\text{or } x = 0.98 \text{ m.}$$

$$34. (a): \text{As } E = \frac{F}{q} = \frac{3 \times 10^{-6} \text{ N}}{2 \times 10^{-9} \text{ C}} = 1.5 \times 10^3 \text{ N C}^{-1}$$

Electrostatic force on a proton

$$= eE = 1.6 \times 10^{-19} \times 1.5 \times 10^3 = 2.4 \times 10^{-16} \text{ N}$$

Gravitational force on a proton

$$= mg = 1.67 \times 10^{-27} \text{ kg} \times 9.8 \text{ m s}^{-2}$$

$$= 1.64 \times 10^{-26} \text{ N}$$

35. (b): When the battery is connected for a long time,

$$V = RI \text{ or } 12 = 6 \times I$$

$$\text{or } I = 2 \text{ A}$$

When the circuit is switched off

The induced emf,

$$\epsilon = -L \frac{dI}{dt} = -10 \left(\frac{0 - 2}{10 \times 10^{-3}} \right) \text{ V} = 2000 \text{ V}$$

36. (a): Let T be the temperature of the mixture.

$$\text{As } U = U_1 + U_2$$

$$\Rightarrow \frac{f}{2}(n_1 + n_2)RT = \frac{f}{2}n_1RT_0 + \frac{f}{2}n_2(2RT_0)$$

$$\text{or } (2 + 4)T = 2T_0 + 8T_0 \quad (\text{as } n_1 = 2, n_2 = 4)$$

$$\text{or } T = (5/3)T_0$$

37. (b): Comparing $y = 3\cos(\pi/4 - 2\omega t)$

$$= 3\cos(2\omega t - \pi/4) \text{ with equation of SHM}$$

$$y = A \cos(\omega t - \phi)$$

$$= A \cos\left(\frac{2\pi}{T}t - \phi\right), \text{ we get}$$

$$\frac{2\pi}{T}t = 2\omega t \text{ or } T = \pi/\omega$$

38. (c): As $\eta_1 = 1 - \frac{T_2}{T_1}$,

$$\therefore \frac{1}{6} = 1 - \frac{T_2}{T_1} \Rightarrow T_2 = \frac{5}{6}T_1$$

$$\text{Further, } \eta_2 = 2 \times \frac{1}{6} = 1 - \frac{(T_2 - 62)}{T_1} = 1 - \left(\frac{5T_1}{6} - 62 \right) \frac{1}{T_1}$$

$$\therefore \frac{5T_1}{6} - 62 = \left(1 - \frac{1}{3} \right) T_1 = \frac{2}{3}T_1$$

$$\Rightarrow \frac{5T_1}{6} - \frac{2}{3}T_1 = 62 \Rightarrow \frac{T_1}{6} = 62$$

$$\therefore T_1 = 372 \text{ K} = (372 - 273)^\circ\text{C} = 99^\circ\text{C}$$

39. (b): As $E = \frac{12375}{\lambda(\text{in } \text{\AA})} = \frac{12375}{4360} = 2.84 \text{ eV}$

$$\therefore K_{\text{max}} = E - W = 1.6 \text{ eV}$$

or, the retarding potential is 1.6 V.

40. (d): $\beta = \frac{\Delta I_c}{\Delta I_b} = 50$, $R_i = 1 \text{ k}\Omega = 10^3 \Omega$

$$\Delta I_{in} = \Delta I_b = \frac{\Delta V_i}{R_i} = \frac{0.01}{10^3} = 10^{-5} \text{ A}$$

$$\therefore \Delta I_c = \beta \Delta I_b = 50 \times 10^{-5} \text{ A} = 500 \mu\text{A}$$

41. (b): Though a freely falling body has an acceleration g , for a freely falling pendulum (which is suspended from a rigid support), the effective value of g is zero. Being in an accelerated reference frame, it also experiences a pseudo-acceleration ($-g$). Since $g = 0$, T becomes infinite.

42. (c)

43. (b): Normal contact force is greater in pushing than in pulling.

44. (b): As the polar ice melts, water so formed flows towards the equator. The moment of inertia of the earth increases. To conserve angular momentum, angular velocity decreases. This increases the length ($T = 2\pi/\omega$) of the day.

45. (b): If the particles moving in same direction lose all their energy, final momentum will become zero, whereas initial momentum is not zero.

46. (d): Both assertion and reason are false. In a battery circuit, the point of lowest potential is the negative terminal and the point of highest potential is the positive terminal of the battery. In a circuit, the current flows from higher potential to lower potential *i.e.*, from positive terminal to negative terminal of the battery.

47. (d): Both assertion and reason are false. The field of the magnet on the nails is non-uniform. It exerts both a net force and a torque on the induced poles of the iron nails.

48. (d): If there is no change in the magnetic flux linked with the coil, there is no induced current. The current induced in a coil is directly proportional to the rate of change of magnetic flux linked with the coil.

49. (d): Excess pressure inside the drop of radius r and surface tension S is

$$P = \frac{2S}{r}$$

As excess of pressure inside the drop is greater in small drop as compared to the large drop, due to which the small drop of liquid resists deforming force better than the large drop.

50. (a): In real gas, intermolecular forces do exist. Work has to be done in changing the distance between the molecules. Therefore, internal energy of real gas is sum of internal K.E. and internal P.E. which are functions of temperature and volume respectively.

51. (c): The ball will not get out of the other end of the hole, because it will execute SHM. On reaching the other end of the hole, its velocity becomes zero and acceleration of ball is maximum and directed towards the centre of earth.

52. (a): $u_x = u \cos\theta$, $a_x = 0$

$$\therefore v_x = u_x + a_x t = u_x = u \cos\theta$$

$$u_y = u \sin\theta; a_y = -g$$

$$\therefore v_y = u \sin\theta - gt = u \sin\theta - g \frac{2u \sin\theta}{g}$$

$$v_y = -u \sin\theta.$$

53. (c): Cement floor being hard, stops the fall of the man immediately *i.e.*, Δt is very small. In case of sand, momentum of fall of the man is reduced to zero in a much longer time, ΔT .

Hence, $f\Delta t = F\Delta T = \Delta P$ as $\Delta t < \Delta T$ so $f \gg F$ (where f and F are force applied by a cement floor and heap of sand respectively.)

54. (c): For conservative forces, the sum of kinetic and potential energies at any point remains constant throughout the motion.

According to this rule,

$$\text{Kinetic energy} + \text{Potential energy} = E = \text{constant}$$

$$\text{or } \Delta T + \Delta U = 0 \text{ or } \Delta T = -\Delta U$$

55. (d): The conductivity of an intrinsic semiconductor is less than that of a lightly doped semiconductor.

56. (a): Time taken for the light emission from an atom $\approx 10^{-8}$ s.

Time taken for release of energy in fission $\approx 10^{-6}$

$$\text{Required ratio} = \frac{10^{-8}}{10^{-6}} = \frac{1}{100} = 1:100$$

57. (a): As $\lambda = \frac{h}{mv}$

$$\text{For constant } v, \lambda \propto \frac{1}{m}$$

λ is significantly measurable only in case of microscopic or sub-microscopic particles.

58. (c): Glass slab will shift the object towards mirror. If it comes between pole and focus image will become virtual.

59. (a): $I_{\max} > 4I_0$ and $I_{\min} = 0$ $\therefore \frac{I_{\max}}{I_{\min}} = \text{infinite}$

If width of one slit is slightly increased $I_{\min} > 0$. Therefore this ratio will be less than infinite.

60. (a): Rate of a nuclear process cannot be altered by altering pressure or temperature. Because any nuclear process involves huge amount of energy.



PRACTICE PAPER 2Q 14

BITSAT

Exam from
14th May to
1st June

1. A particle starts from rest and traverses a distance $2x$ with uniform acceleration, then moves uniformly over a further distance $4x$ and finally comes to rest after moving a further distance $6x$ under uniform retardation. Assuming entire motion to be rectilinear motion, the ratio of average speed over the journey to the maximum speed on its way is

(a) $\frac{4}{5}$ (b) $\frac{3}{5}$ (c) $\frac{2}{5}$ (d) $\frac{1}{5}$

2. A car is moving in a circular horizontal track of radius 10 m with a constant speed of 10 m/s. A plumb bob is suspended from the roof of the car by a light rod of length 1 m. The angle made by the rod with the vertical is

(a) zero (b) 30° (c) 45° (d) 60°

3. A simple pendulum has time period T . A uniform rod, whose length is the same as that of the pendulum, undergoes small oscillations about its upper end. Its time period of oscillation will be

(a) $< T$ (b) T
(c) $> T$
(d) may be (a), (b) or (c) depending on whether T is $<$, equal to or > 2 seconds

4. A metal ball immersed in alcohol weighs W_1 at 0°C and W_2 at 59°C . The coefficient of cubical expansion of the metal is less than that of alcohol. Assuming that the density of the metal is large compared to that of alcohol, it can be shown that

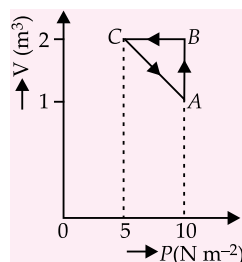
(a) $W_1 > W_2$ (b) $W_1 < W_2$
(c) $W_1 = W_2$ (d) $W_1 = 2W_2$

5. At what temperature, the average kinetic energy of translatory motion of a gas molecule will be equal to that of an electron accelerated through a potential difference of 10 V? Boltzmann constant, $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$

(a) $2.42 \times 10^3 \text{ K}$ (b) $7.73 \times 10^3 \text{ K}$
(c) $2.42 \times 10^4 \text{ K}$ (d) $7.73 \times 10^4 \text{ K}$

6. An ideal gas is taken through the cycle $A \rightarrow B \rightarrow C \rightarrow A$, as shown in figure. If the net heat supplied to the

gas in the cycle is 5 J, work done by the gas in the process $C \rightarrow A$ is



(a) -5 J (b) -10 J (c) -15 J (d) -20 J

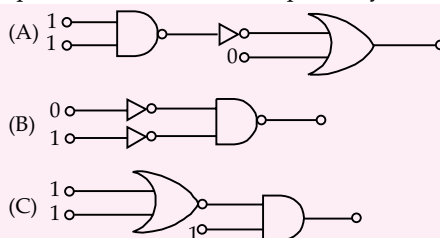
7. When a stretched wire and a tuning fork are sounded together, 5 beats per second are produced, when length of wire is 95 cm or 100 cm, frequency of fork is

(a) 90 (b) 100 (c) 105 (d) 195

8. Three point charges $+q$, $-2q$ and $+q$ are placed at points $(x = 0, y = a, z = 0)$, $(x = 0, y = 0, z = 0)$ and $(x = a, y = 0, z = 0)$ respectively. The magnitude and direction of the electric dipole moment vector of this charge assembly are

(a) $\sqrt{2} qa$ along the line joining the points $(x = 0, y = 0, z = 0)$ and $(x = a, y = a, z = 0)$.
(b) qa along the line joining the points $(x = 0, y = 0, z = 0)$ and $(x = a, y = a, z = 0)$.
(c) $\sqrt{2} qa$ along $+x$ direction
(d) $\sqrt{2} qa$ along $+y$ direction.

9. In the following combinations of logic gates, the outputs of A, B and C are respectively

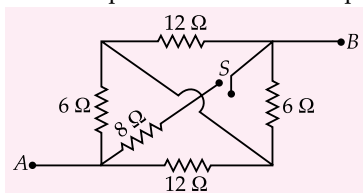


(a) 0, 1, 1 (b) 0, 1, 0 (c) 1, 1, 0 (d) 1, 0, 1

10. A car of mass 400 kg, travelling at 72 km h^{-1} crashes into a truck of mass 4000 kg, travelling at 9 km h^{-1} in the same direction. The car bounces back at a speed of 18 km h^{-1} . The speed of the truck after the impact is
(a) 9 km h^{-1} (b) 18 km h^{-1}
(c) 27 km h^{-1} (d) 36 km h^{-1}
11. A wire of length 2 m is made from 10 cm^3 of copper. A force F is applied so that its length increases by 2 mm. Another wire of length 8 m is made from the same volume of copper. If the force F is applied to it, its length will increase by
(a) 0.8 cm (b) 1.6 cm (c) 2.4 cm (d) 3.2 cm
12. The magnetic field due to a current carrying circular loop of radius 3 cm at a point on the axis at a distance of 4 cm from the centre is $54 \mu\text{T}$. What will be its value at the centre of the loop?
(a) $250 \mu\text{T}$ (b) $150 \mu\text{T}$ (c) $125 \mu\text{T}$ (d) $75 \mu\text{T}$
13. The input resistance of a silicon transistor is 100Ω . Base current is changed by $40 \mu\text{A}$ which results in a change in collector current by 2 mA. This transistor is used as a common emitter amplifier with a load resistance of $4 \text{ k}\Omega$. The voltage gain of the amplifier is
(a) 2000 (b) 3000
(c) 4000 (d) 1000
14. Vector \vec{A} has a magnitude of 5 units, lies in the xy -plane and points in a direction 120° from the direction of increasing x . Vector \vec{B} has a magnitude of 9 units and points along the z -axis. The magnitude of cross product $\vec{A} \times \vec{B}$ is
(a) 30 (b) 35 (c) 40 (d) 45
15. Calculate the acceleration due to gravity on the surface of a pulsar of mass $M = 1.98 \times 10^{30} \text{ kg}$ and radius $R = 12 \text{ km}$ rotating with time period $T = 0.041$ seconds. (Take $G = 6.67 \times 10^{-11} \text{ MKS}$)
(a) $9.2 \times 10^{11} \text{ m s}^{-2}$ (b) $8.15 \times 10^{11} \text{ m s}^{-2}$
(c) $7.32 \times 10^{11} \text{ m s}^{-2}$ (d) $6.98 \times 10^{11} \text{ m s}^{-2}$
16. An alternating emf $e = 220\sqrt{2} \sin 100t \text{ V}$ is applied to a capacitor $1 \mu\text{F}$. The current flowing through the capacitor is
(a) 22 mA (b) 12 mA
(c) 32 mA (d) 42 mA
17. A tuning fork and a sonometer wire sounded together produce 4 beats per second when the length of the wire is 95 cm or 100 cm. The frequency of the tuning fork is
(a) 156 Hz (b) 152 Hz
(c) 148 Hz (d) 150 Hz
18. Two springs A and B are identical except that A is stiffer than B i.e., $k_A > k_B$. If the two springs are stretched by the same force, then
(a) more work is done on B i.e., $W_B > W_A$.
(b) more work is done on A i.e., $W_A > W_B$.
(c) work done on A and B are equal.
(d) work done depends upon the way in which they are stretched.
19. A wheel turning with angular speed of 30 rev s^{-1} is brought to rest with a constant acceleration. It turns 60 rev before it stops. The time that elapses before it stops is
(a) 2 s (b) 4 s (c) 5 s (d) 6 s
20. A physical quantity X is given by $X = \frac{2k^3 l^2}{m\sqrt{n}}$
The percentage error in the measurements of k , l , m and n are 1%, 2%, 3% and 4% respectively. The value of X is uncertain by
(a) 8% (b) 10%
(c) 12% (d) none of these
21. A rope is wound round a hollow cylinder of mass 3 kg and radius 40 cm. If the rope is pulled with a force of 30 N, angular acceleration of the cylinder will be
(a) 10 rad s^{-2} (b) 15 rad s^{-2}
(c) 20 rad s^{-2} (d) 25 rad s^{-2}
22. The acceleration due to gravity at the poles and the equator is g_p and g_e respectively. If the earth is a sphere of radius R and rotating about its axis with angular speed ω , then $g_p - g_e$ is given by
(a) $\frac{\omega^2}{R}$ (b) $\frac{\omega^2}{R^2}$ (c) $\omega^2 R^2$ (d) $\omega^2 R$
23. The half-life of ^{60}Co is approximately 5.25 years. In a sample containing 1 g of freshly prepared ^{60}Co , how much of the isotope will be left after 21 years?
(a) 125 mg (b) 62.5 mg
(c) 31.25 mg (d) nothing will be left
24. A wire of length 100 cm is connected to a cell of emf 2 V and negligible internal resistance. The resistance of the wire is 3Ω . The additional resistance required to produce a potential difference of 1 millivolt per cm is
(a) 60Ω (b) 47Ω (c) 57Ω (d) 35Ω
25. Two slits separated by a distance of 1 mm are illuminated with red light of wavelength $6.5 \times 10^{-7} \text{ m}$. The interference fringes are observed on a screen placed 1 m from the slits. The distance between the third dark fringe and the fifth bright fringe is equal to

- (a) 0.65 mm (b) 1.63 mm
(c) 3.25 mm (d) 4.88 mm

26. When a dc voltage of 200 V is applied to a coil of self inductance $(2\sqrt{3}/\pi)$ H, a current of 1 A flows through it. But by replacing dc source with ac source of 200 V, the current in the coil is reduced to 0.5 A. Then the frequency of ac supply is
(a) 100 Hz (b) 75 Hz
(c) 60 Hz (d) 50 Hz
27. A compound microscope has an eye piece of focal length 10 cm and an objective of focal length 4 cm. Find the magnification, if an object is kept at a distance of 5 cm from the objective, so that the final image is formed at the least distance of distinct vision 20 cm.
(a) 12 (b) 11 (c) 10 (d) 13
28. According to Bohr's theory the energy of an electron in hydrogen atom starts corresponding to $n = 1, 2, 3, 4$ is respectively -13.6 eV, -3.4 eV, -1.51 eV and -0.85 eV. In order to obtain emission of H_β line of Balmer series, the energy that has to be given to a normal hydrogen atom is
(a) 12.75 eV (b) 14.45 eV
(c) 2.55 eV (d) 4.25 eV
29. The equivalent resistance between points A and B with switch S open and closed are respectively

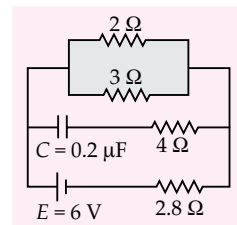


- (a) 4 Ω , 8 Ω (b) 8 Ω , 4 Ω
(c) 6 Ω , 9 Ω (d) 9 Ω , 6 Ω
30. If a rod has a resistance 4 Ω and if rod is turned as half cycle, then resistance along diameter is
(a) 1.56 Ω (b) 2.44 Ω
(c) 4 Ω (d) 2 Ω
31. A solenoid of length 30 cm with 10 turns per centimetre and area of cross-section 40 cm² completely surrounds another co-axial solenoid of same length, area of cross-section 20 cm² with 40 turns per centimeter. The mutual inductance of the system is
(a) 10 H (b) 8 H
(c) 3 mH (d) 30 mH
32. A prism of refractive index μ and angle A is placed in the minimum deviation position. If the angle of

minimum deviation is A , then the value of A in terms of μ is

- (a) $\sin^{-1}\left(\frac{\mu}{2}\right)$ (b) $\sin^{-1}\left(\sqrt{\frac{\mu-1}{2}}\right)$
(c) $2\cos^{-1}\left(\frac{\mu}{2}\right)$ (d) $\cos^{-1}\left(\frac{\mu}{2}\right)$

33. In the circuit shown, the internal resistance of the cell is negligible. The steady state current in the 2 Ω resistor is



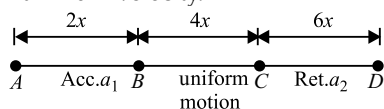
- (a) 0.6 A
(b) 0.9 A
(c) 1.2 A
(d) 1.5 A
34. Interference fringes were produced in Young's double slit experiment using light of wavelength 5000 Å. When a film of material 2.5×10^{-3} cm thick was placed over one of the slits, the fringe pattern shifted by a distance equal to 20 fringe widths. The refractive index of the material of the film is
(a) 1.25 (b) 1.33 (c) 1.4 (d) 1.5
35. Consider an $n-p-n$ transistor amplifier in common emitter configuration. The current gain of the transistor is 100. If the collector current changes by 1 mA, what will be the change in emitter current?
(a) 1.1 mA (b) 1.01 mA
(c) 0.01 mA (d) 10 mA
36. When radiation of the wavelength λ is incident on a metallic surface, the stopping potential is 4.8 V. If the same surface is illuminated with radiation of double the wavelength, then the stopping potential becomes 1.6 V. Then the threshold wavelength for the surface is
(a) 2λ (b) 4λ (c) 6λ (d) 8λ
37. The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectrons emission from this substance is approximately
(a) 540 nm (b) 400 nm
(c) 310 nm (d) 220 nm
38. The potential difference between the plates of a parallel plate capacitor is changing at the rate of 10^6 V s⁻¹. If the capacitance is 2 μ F, the displacement current in the dielectric of the capacitor will be
(a) 1 A (b) 2 A (c) 3 A (d) 4 A
39. The equation $y = A \sin 2\pi \left[\frac{t}{T} - \frac{x}{\lambda} \right]$ where the symbols carry the usual meaning and A , T and λ are positive represents a wave of

- (a) amplitude $2A$ (b) period $\frac{T}{\lambda}$
 (c) speed $\frac{\lambda}{T}$
 (d) velocity in negative x -direction

40. A chain of 5 links each of mass 0.1 kg is lifted vertically with a constant acceleration 1.2 m s^{-2} . The force of interaction between the top link and the one immediately below it is
 (a) 5.5 N (b) 4.4 N
 (c) 3.04 N (d) 7.6 N

SOLUTIONS

1. (b): Refer figure, let t_1 , t_2 and t_3 be the times taken by the particle to cover the distances $2x$, $4x$ and $6x$ respectively. Let v be the velocity of the particle at B i.e. maximum velocity.



The particle moves with uniform acceleration from A to B.

For motion from A to B,

$$\text{Average velocity} = \frac{0+v}{2} = \frac{v}{2}$$

$$\text{Time taken, } t_1 = \frac{2x}{v/2} = \frac{4x}{v}$$

Particle moves with uniform velocity from B to C,

$$\text{time taken, } t_2 = \frac{4x}{v}$$

The particle moves with uniform retardation from C to D.

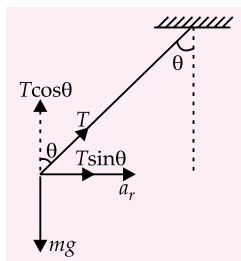
$$\text{time taken, } t_3 = \frac{6x}{(0+v)/2} = \frac{12x}{v}$$

$$\text{Total time taken} = t_1 + t_2 + t_3$$

$$= \frac{4x}{v} + \frac{4x}{v} + \frac{12x}{v} = \frac{20x}{v}$$

$$v_{\text{av}} = \frac{2x + 4x + 6x}{20x/v} = \frac{12v}{20} \text{ or } \frac{v_{\text{av}}}{v} = \frac{12}{20} = \frac{3}{5}$$

2. (c):



The radial acceleration is

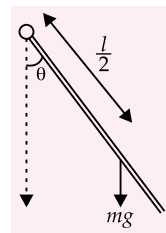
$$a_r = \frac{v^2}{r} = \frac{(10 \text{ m s}^{-1})^2}{10 \text{ m}} = 10 \text{ m s}^{-2}.$$

If T = tension in the rod then $T \cos \theta = mg$,

$$T \sin \theta = m a_r.$$

$$\text{or } \tan \theta = \frac{a_r}{g} = 1 \text{ or } \theta = 45^\circ.$$

3. (a): $T = 2\pi\sqrt{l/g}$
 where l = length of simple pendulum = length of rod.



$$\tau = (mg) \frac{l}{2} \sin \theta.$$

$$\text{For small } \theta, \tau = \frac{1}{2} mgl \theta = -I\alpha = -\left(\frac{ml^2}{3}\right) \alpha$$

$$\text{or } \alpha = -\left(\frac{3g}{2l}\right) \theta.$$

Comparing with the equation, $\alpha = \frac{d^2\theta}{dt^2} = -\omega^2\theta$ we get

$$\text{Time period} = 2\pi\sqrt{\frac{2l}{3g}}.$$

Hence, time period of rod is less than time period of simple pendulum.

4. (a): Let V_0 , V_t = volume of the metal ball at 0°C and $t^\circ\text{C}$ respectively.

ρ_0 , ρ_t = density of alcohol at 0°C and $t^\circ\text{C}$ respectively. Then

$$W_1 = W_0 - V_0\rho_0g$$

$$\text{and } W_2 = W_t - V_t\rho_tg$$

$$\text{where } V_t = V_0(1 + \gamma_m t) \text{ and } \rho_t = \frac{\rho_0}{(1 + \gamma_a t)} \quad \dots(i)$$

$$\therefore \text{Upthrust at } t^\circ\text{C} = V_t\rho_tg$$

$$= V_0(1 + \gamma_m t) \times \frac{\rho_0}{(1 + \gamma_a t)}g = V_0\rho_0 \frac{(1 + \gamma_m t)}{(1 + \gamma_a t)}g \text{ (using (i))}$$

As $\gamma_m < \gamma_a$, hence upthrust at $t^\circ\text{C}$ is less than at 0°C . It means upthrust has been decreased with increase in temperature. Due to which $W_1 > W_2$.

5. (d): Mean translational K.E. per molecule of a gas
 $= \frac{3}{2} kT$

and kinetic energy of electron when accelerated through a potential difference V is

$$eV = \frac{3}{2}kT$$

$$\text{or } T = \frac{2eV}{3k} = \frac{2 \times (1.6 \times 10^{-19}) \times 10}{3 \times 1.38 \times 10^{-23}} = 7.73 \times 10^4 \text{ K}$$

6. (a): $\Delta W_{AB} = P\Delta V = 10(2 - 1) = 10 \text{ J}$

$$\Delta W_{BC} = 0,$$

because V is constant.

From first law of thermodynamics,

$$\Delta Q = \Delta W + \Delta U$$

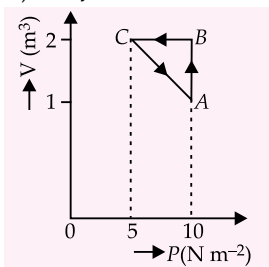
As ABCA is a cyclic process,

$$\Delta U = 0$$

$$\therefore \Delta Q = \Delta W_{AB} + \Delta W_{BC} + \Delta W_{CA}$$

$$= \Delta W_{AB} + \Delta W_{CA}$$

$$\text{or } \Delta W_{CA} = \Delta Q - \Delta W_{AB} = 5 - 10 = -5 \text{ J}.$$



7. (d): Let the frequency of tuning fork be n .

Suppose $l_1 = 95 \text{ cm}$ has frequency n_1 and

$l_2 = 100 \text{ cm}$ has frequency n_2 ($< n_1$)

$$\text{Now, } n_1 - n = 5 \quad \dots(i)$$

$$n - n_2 = 5 \quad \dots(ii)$$

$$\text{Adding, we get } n_1 - n_2 = 10 \quad \dots(iii)$$

$$\text{Also, } \frac{n_1}{n_2} = \frac{l_2}{l_1} = \frac{100}{95}$$

$$n_1 = \frac{100}{95} n_2$$

From (iii),

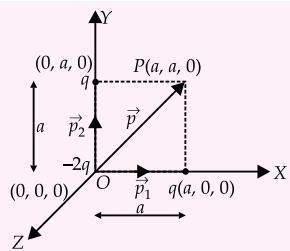
$$\frac{100}{95} n_2 - n_2 = 10, n_2 = 190$$

From (ii),

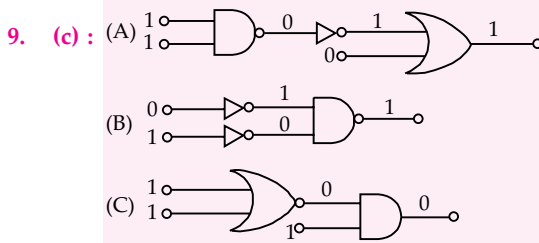
$$n = n_2 + 5 = 190 + 5 = 195 \text{ Hz}.$$

8. (a): The given charge assembly is equivalent to two dipoles. One dipole of charges $-q$ and $+q$ has dipole moment \vec{p}_1 along positive X-direction and other dipole of charges $-q$ and $+q$ has dipole moment \vec{p}_2 along positive Y-direction. The resultant dipole moment \vec{p} has magnitude,

$$p = \sqrt{p_1^2 + p_2^2} = \sqrt{q^2 a^2 + q^2 a^2} = \sqrt{2} qa$$



\vec{p} is directed along \overrightarrow{OP} , where P is $(a, a, 0)$.



The outputs of A, B and C are respectively 1, 1, 0.

10. (b): Here, $m_1 = 400 \text{ kg}$

$$u_1 = 72 \text{ km h}^{-1} = 72 \times \frac{5}{18} \text{ m s}^{-1} = 20 \text{ m s}^{-1}$$

$$m_2 = 4000 \text{ kg}$$

$$u_2 = 9 \text{ km h}^{-1} = 9 \times \frac{5}{18} \text{ m s}^{-1} = 2.5 \text{ m s}^{-1}$$

$$v_1 = -18 \text{ km h}^{-1} = -18 \times \frac{5}{18} \text{ m s}^{-1} = -5 \text{ m s}^{-1}$$

According to law of conservation of linear momentum, we get

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

$$400 \times 20 + 4000 \times 2.5 = 400 \times (-5) + 4000 \times v_2$$

$$20 + 25 = -5 + 10v_2$$

$$45 = -5 + 10v_2$$

$$v_2 = 5 \text{ m s}^{-1} = 5 \times \frac{18}{5} \text{ km h}^{-1} = 18 \text{ km h}^{-1}$$

11. (d): As in question, materials are same

$$\therefore Y = Y_1 = Y_2$$

$$Y = \frac{F}{A_1} \frac{l_1}{\Delta l_1} = \frac{F l_2}{A_2 \Delta l_2} \text{ and } V = A_1 l_1 = A_2 l_2$$

$$\therefore \frac{F}{V} \frac{l_1^2}{\Delta l_1} = \frac{F l_2^2}{V \Delta l_2}$$

$$\text{or } \Delta l_2 = \frac{l_2^2}{l_1^2} \Delta l_1 = \frac{8^2}{2^2} \times 2 \times 10^{-3} = 32 \text{ mm} = 3.2 \text{ cm}$$

12. (a): The magnetic field at a point on the axis of circular current carrying loop is given by

$$B = \frac{\mu_0}{4\pi} \frac{2\pi I R^2}{(R^2 + x^2)^{3/2}}$$

where R is the radius of the loop, x is the distance of the point on the axis from the centre of the loop

$$\text{Here, } R = 3 \text{ cm} = 3 \times 10^{-2} \text{ m}, x = 4 \text{ cm} = 4 \times 10^{-2} \text{ m}, B = 54 \times 10^{-6} \text{ T}$$

$$\begin{aligned} \therefore 54 \times 10^{-6} &= \frac{\mu_0}{4\pi} \frac{2\pi I (3 \times 10^{-2})^2}{(3^2 + 4^2)^{3/2} \times 10^{-6}} \\ &= \frac{\mu_0}{4\pi} \frac{2\pi I 9}{125 \times 10^{-2}} \quad \dots(i) \end{aligned}$$

Magnetic field at the centre of the loop is

$$B' = \frac{\mu_0}{4\pi} \frac{2\pi I}{R} = \frac{\mu_0}{4\pi} \frac{2\pi I}{3 \times 10^{-2}} \quad \dots(ii)$$

Dividing (ii) by (i), we get

$$\frac{B'}{54 \times 10^{-6}} = \frac{125 \times 10^{-2}}{9 \times 3 \times 10^{-2}}$$

$$\text{or } B' = 250 \times 10^{-6} \text{ T} = 250 \mu\text{T}$$

13. (a) : Here,

Input resistance, $R_i = 100 \Omega$

Change in base current, $\Delta I_B = 40 \mu\text{A}$

Change in collector current, $\Delta I_C = 2 \text{ mA}$

Load resistance, $R_L = 4 \text{ k}\Omega = 4 \times 10^3 \Omega$

$$\begin{aligned} \text{Current gain, } \beta &= \frac{\Delta I_C}{\Delta I_B} = \frac{2 \text{ mA}}{40 \mu\text{A}} \\ &= \frac{2 \times 10^{-3} \text{ A}}{40 \times 10^{-6} \text{ A}} = 50 \end{aligned}$$

Voltage gain of the amplifier is

$$A_V = \beta \frac{R_L}{R_i} = 50 \times \frac{4 \times 10^3}{100} = 2000$$

14. (d) : Here,

$$\begin{aligned} \vec{A} &= 5 \cos 120^\circ \hat{i} + 5 \sin 120^\circ \hat{j} \\ &= 5 \left(\frac{-1}{2} \right) \hat{i} + 5 \left(\frac{\sqrt{3}}{2} \right) \hat{j} = \frac{-5}{2} \hat{i} + \frac{5\sqrt{3}}{2} \hat{j} \end{aligned}$$

$$\vec{B} = 9\hat{k}$$

$$\begin{aligned} \vec{A} \times \vec{B} &= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{-5}{2} & \frac{5\sqrt{3}}{2} & 0 \\ 0 & 0 & 9 \end{vmatrix} \\ &= \hat{i} \left(\frac{45\sqrt{3}}{2} - 0 \right) + \hat{j} \left(0 - \left(\frac{-45}{2} \right) \right) + \hat{k} (0 - 0) \\ &= \frac{45\sqrt{3}}{2} \hat{i} + \frac{45}{2} \hat{j} \\ |\vec{A} \times \vec{B}| &= \sqrt{\left(\frac{45\sqrt{3}}{2} \right)^2 + \left(\frac{45}{2} \right)^2} \\ &= \frac{45}{2} \sqrt{(\sqrt{3})^2 + (1)^2} \\ &= \frac{45}{2} \sqrt{3+1} = \frac{45}{2} \times 2 = 45 \end{aligned}$$

15. (a) : Here, $G = 6.67 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2}$

Mass of a pulsar, $M = 1.98 \times 10^{30} \text{ kg}$

Radius of the pulsar, $R = 12 \text{ km} = 12 \times 10^3 \text{ m}$

Acceleration due to gravity on the surface of the pulsar is

$$g = \frac{GM}{R^2}$$

Substituting the given numerical values, we get

$$\begin{aligned} g &= \frac{(6.67 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2})(1.98 \times 10^{30} \text{ kg})}{(12 \times 10^3 \text{ m})^2} \\ &= 0.092 \times 10^{13} \text{ m s}^{-2} = 9.2 \times 10^{11} \text{ m s}^{-2} \end{aligned}$$

16. (a) : Compare $e = 220\sqrt{2} \sin 100t \text{ V}$ with

$e = e_0 \sin \omega t$, we get

$$e_0 = 220\sqrt{2} \text{ V}, \quad \omega = 100 \text{ rad s}^{-1}$$

$$e_{\text{rms}} = \frac{e_0}{\sqrt{2}} = \frac{220\sqrt{2}}{\sqrt{2}} \text{ V} = 220 \text{ V}$$

The capacitive reactance is

$$X_C = \frac{1}{\omega C} = \frac{1}{100 \times 1 \times 10^{-6}} = 10^4 \Omega$$

The current flowing through the capacitor is

$$I_{\text{rms}} = \frac{e_{\text{rms}}}{X_C} = \frac{220 \text{ V}}{10^4 \Omega} = 220 \times 10^{-4} \text{ A} = 22 \text{ mA}$$

17. (a) : The frequencies of the wire when its vibrating length is $L_1 = 95 \text{ cm}$ and when its vibrating length $L_2 = 100 \text{ cm}$ are given by

$$v_1 = \frac{p}{2L_1} \sqrt{\frac{T}{\mu}} \quad \text{and} \quad v_2 = \frac{p}{2L_2} \sqrt{\frac{T}{\mu}}$$

$$\text{Dividing, we get } \frac{v_1}{v_2} = \frac{L_2}{L_1} = \frac{100}{95} \quad \dots(i)$$

Thus $v_1 > v_2$.

Let v is the frequency of the tuning fork. Then

$$v_1 - v = 4 \text{ and } v - v_2 = 4$$

Adding, we get $v_1 - v_2 = 8$...(ii)

Using (ii) in (i) we get

$$v_1 = 160 \text{ Hz and } v_2 = 152 \text{ Hz.}$$

$$\text{As } v_1 - v = 4 \text{ or } v = v_1 - 4 = 160 - 4 = 156 \text{ Hz.}$$

18. (a) : As $F = k_A x_A = k_B x_B$ or $\frac{x_A}{x_B} = \frac{k_B}{k_A}$...(i)

$$W_A = \frac{1}{2} k_A x_A^2; \quad W_B = \frac{1}{2} k_B x_B^2$$

$$\frac{W_A}{W_B} = \frac{k_A x_A^2}{k_B x_B^2} = \frac{k_A k_B^2}{k_B k_A^2} = \frac{k_B}{k_A} \quad \text{(Using (i))}$$

$$\therefore k_A > k_B$$

Hence $W_B > W_A$. So more work is done on B.

19. (b) : Here,

$$\text{Initial angular speed, } \omega_i = 2\pi \times 30 = 60\pi \text{ rad s}^{-1}$$

Final angular speed, $\omega_f = 0$
Angular displacement, $\theta = 2\pi \times 60 = 120\pi$ rad

$$\text{As } \omega_f^2 - \omega_i^2 = 2\alpha\theta$$

$$\therefore (0)^2 - (60\pi)^2 = 2 \times \alpha \times 120\pi$$

$$\alpha = -\frac{(60\pi)^2}{2 \times 120\pi} = -15\pi \text{ rad s}^{-2} \quad \dots(i)$$

$$\text{As } \omega_f = \omega_i + \alpha t$$

$$\therefore t = \frac{\omega_f - \omega_i}{\alpha} = \frac{0 - 60\pi}{(-15\pi)} = 4 \text{ s} \quad (\text{Using (i)})$$

$$20. \text{ (c) : Given : } X = \frac{2k^3 l^2}{m\sqrt{n}}$$

$$\therefore \frac{\Delta X}{X} = 3\frac{\Delta k}{k} + 2\frac{\Delta l}{l} + \frac{\Delta m}{m} + \frac{1}{2}\frac{\Delta n}{n}$$

Percentage error in X

$$\begin{aligned} \frac{\Delta X}{X} \times 100 &= \left(3\frac{\Delta k}{k} + 2\frac{\Delta l}{l} + \frac{\Delta m}{m} + \frac{1}{2}\frac{\Delta n}{n} \right) \times 100 \\ &= 3 \times 1\% + 2 \times 2\% + 3\% + \frac{1}{2} \times 4\% \\ &= 3\% + 4\% + 3\% + 2\% = 12\% \end{aligned}$$

Hence, the value of X is uncertain by 12%.

21. (d) : Moment of inertia of the hollow cylinder about its axis is

$$I = MR^2 = (3 \text{ kg})(0.4 \text{ m})^2 = 0.48 \text{ kg m}^2$$

Torque applied on the cylinder

$$\tau = FR$$

$$= 30 \text{ N} \times 0.4 \text{ m} = 12 \text{ N m}$$

Angular acceleration (α) of the cylinder

$$\alpha = \frac{\tau}{I} = \frac{12}{0.48} = 25 \text{ rad s}^{-2}$$

22. (d) : Acceleration due to gravity at a place of latitude λ due to the rotation of earth is

$$g' = g - R\omega^2 \cos^2 \lambda$$

$$\text{At equator } \lambda = 0^\circ, \cos 0^\circ = 1$$

$$\therefore g' = g_e = g - R\omega^2$$

$$\text{At poles, } \lambda = 90^\circ, \cos 90^\circ = 0$$

$$\therefore g' = g_p = g$$

$$\therefore g_p - g_e = g - (g - R\omega^2) = R\omega^2$$

23. (b) : Here, $T_{1/2} = 5.25$ years

$$t = 21 \text{ years}$$

No. of half lives,

$$n = \frac{t}{T_{1/2}} = \frac{21 \text{ years}}{5.25 \text{ years}} = 4$$

Amount of sample left

$$= \left(\frac{1}{2} \right)^4 \times 1 \text{ g} = \frac{1}{16} \text{ g}$$

$$= \frac{1000}{16} \text{ mg} = 62.5 \text{ mg}$$

24. (c) : Potential difference across wire

$$= I \times 3 = \frac{2 \times 3}{(3 + R)}$$

$$\begin{aligned} \text{Potential gradient} &= \frac{6}{(3 + R)} \frac{1}{100} \\ &= 10^{-3} \text{ V cm}^{-1} \end{aligned}$$

(Given)

$$\text{or } 60 = 3 + R \text{ or } R = 57 \Omega$$

25. (b) : Here, $d = 1 \text{ mm} = 10^{-3} \text{ m}$, $\lambda = 6.5 \times 10^{-7} \text{ m}$
 $D = 1 \text{ m}$

$$x_5 = n\lambda \frac{D}{d} = 5 \times 6.5 \times 10^{-7} \times \frac{1}{10^{-3}} = 32.5 \times 10^{-4} \text{ m}$$

$$\begin{aligned} x_3 &= (2n - 1) \frac{\lambda D}{2d} = \frac{(2 \times 3 - 1) \times 6.5 \times 10^{-7} \times 1}{2 \times 10^{-3}} \\ &= 16.25 \times 10^{-4} \text{ m} \end{aligned}$$

$$\begin{aligned} x_5 - x_3 &= (32.5 - 16.25) \times 10^{-4} \text{ m} \\ &= 16.25 \times 10^{-4} \text{ m} = 1.63 \text{ mm} \end{aligned}$$

26. (d) : Resistance of coil, $R = \frac{200 \text{ V}}{1 \text{ A}} = 200 \Omega$

$$\text{With ac source, } I = \frac{200}{\sqrt{R^2 + X_L^2}} \text{ or } 0.5 = \frac{200}{\sqrt{R^2 + X_L^2}}$$

$$\text{or } R^2 + (2\pi\nu L)^2 = (400)^2$$

$$\text{or } \left(2\pi\nu \times \frac{2\sqrt{3}}{\pi} \right)^2 = (400)^2 - (200)^2 = 200 \times 600$$

$$\text{or } 4\sqrt{3}\nu = 2\sqrt{3} \times 100 \text{ or } \nu = 50 \text{ Hz.}$$

27. (a) : Here, $u_o = -5 \text{ cm}$, $f_o = 4 \text{ cm}$,
 $f_e = 10 \text{ cm}$, $D = 20 \text{ cm}$

According to lens formula

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o}$$

$$\text{or } \frac{1}{v_o} = \frac{1}{f_o} + \frac{1}{u_o}$$

Substituting the given values, we get

$$\frac{1}{v_o} = \frac{1}{4} + \frac{1}{-5} = \frac{1}{4} - \frac{1}{5} = \frac{1}{20}$$

$$v_o = 20 \text{ cm}$$

$$\text{Magnification, } M = \frac{v_o}{|u_o|} \left(1 + \frac{D}{f_e} \right)$$

$$= \frac{20}{5} \left(1 + \frac{20}{10} \right) = 12 \text{ cm}$$

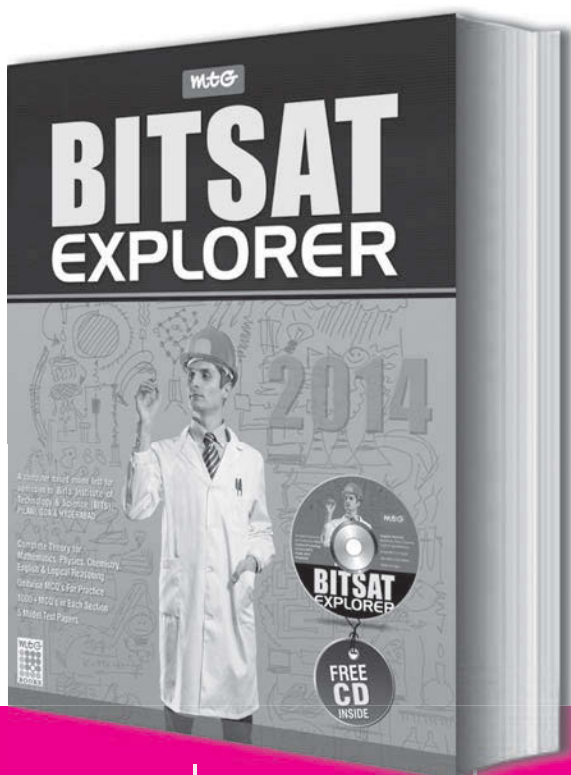
28. (a) : The hydrogen atom in the ground state (-13.6 eV) must be excited to the energy level with $n = 4$ (i.e., -0.85 eV) so as to have H_β line.



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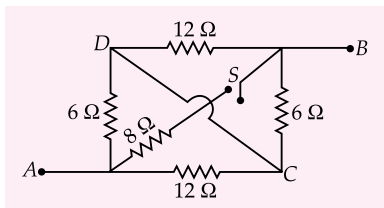
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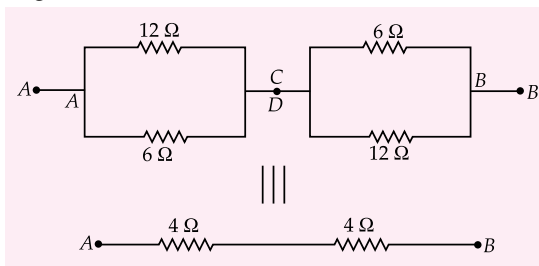


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29. (b) :



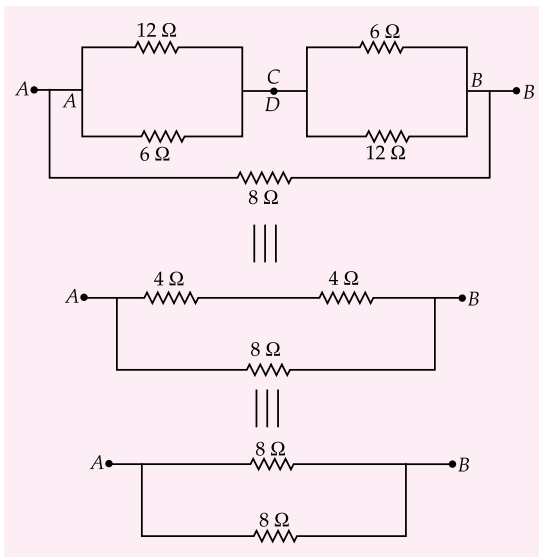
When switch S is open, the corresponding equivalent circuit diagram is as shown in the figure.



The equivalent resistance between A and B is

$$R_{eq} = \frac{12 \times 6}{12 + 6} + \frac{6 \times 12}{6 + 12} = 4 + 4 = 8 \Omega$$

When switch S is closed, the corresponding equivalent circuit diagram is as shown in the figure below



The equivalent resistance A and B is

$$R'_{eq} = \frac{8 \times 8}{8 + 8} = 4 \Omega$$

30. (c) : When the wire is turned as half cycle, there is no change in the dimensions of the wire *i.e.* the length of wire is l and area of cross section of the wire is A . Hence the resistance of bent wire is equal to the original resistance of the wire.

31. (c) : Mutual inductance of the system,

$$M = \mu_0 n_1 n_2 A_2 l$$

where A_2 is the area of inner solenoid

$$n_1 = 10 \text{ cm}^{-1} = 1000 \text{ m}^{-1}$$

$$n_2 = 40 \text{ cm}^{-1} = 4000 \text{ m}^{-1}$$

$$l = 30 \text{ cm} = 30 \times 10^{-2} \text{ m}$$

$$A_2 = 20 \text{ cm}^2 = 20 \times 10^{-4} \text{ m}^2$$

$$\therefore M = 4\pi \times 10^{-7} \times 1000 \times 4000 \times 20 \times 10^{-4} \times 30 \times 10^{-2} = 301.44 \times 10^{-5} \text{ H} = 3 \text{ mH}$$

$$32. (c) : \text{As } \mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Here, $\delta_m = A$

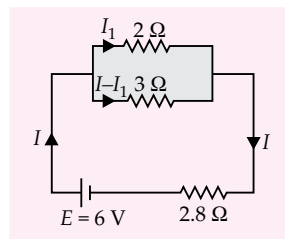
$$\therefore \mu = \frac{\sin A}{\sin\left(\frac{A}{2}\right)} = \frac{2 \sin\left(\frac{A}{2}\right) \cos\left(\frac{A}{2}\right)}{\sin\left(\frac{A}{2}\right)} = 2 \cos\left(\frac{A}{2}\right)$$

$$A = 2 \cos^{-1}\left(\frac{\mu}{2}\right)$$

33. (b) : Given : Capacitance of the capacitor

(C) = $0.2 \mu\text{F}$ and emf of cell (E) = 6 V .

Reactance of a capacitor for a cell, which is a DC source, is infinity. Therefore, no current flows in 4Ω resistance.



Resistances 2Ω and 3Ω (both in upper arm) are connected in parallel.

Therefore, their equivalent resistance

$$(R') = \frac{2 \times 3}{2 + 3} = 1.2 \Omega$$

Now, R' and 2.8Ω are in series combination.

Therefore, equivalent resistance of the circuit,

$$R = R' + 2.8 = 1.2 + 2.8 = 4 \Omega$$

Current drawn in the circuit,

$$I = \frac{E}{R} = \frac{6}{4} = 1.5 \text{ A}$$

From figure,

$$I_1 \times 2 = (I - I_1) \times 3$$

$$2I_1 = 3I - 3I_1$$

$$5I_1 = 3I$$

$$I_1 = \frac{3 \times 1.5}{5} = 0.9 \text{ A}$$

34. (c) : Fringe width $\beta = \frac{\lambda D}{d}$... (i)

where D is the distance between the screen and slit and d is the distance between two slits.

When a film of thickness t and refractive index μ is placed over one of the slit, the fringe pattern is shifted by distance S and is given by

$$S = \frac{(\mu - 1)tD}{d} \quad \dots (ii)$$

Given, $S = 20\beta$... (iii)

From equations (i), (ii) and (iii) we get,

$$(\mu - 1)t = 20\lambda$$

or $(\mu - 1) = \frac{20\lambda}{t} = \frac{20 \times 5000 \times 10^{-8} \text{ cm}}{2.5 \times 10^{-3} \text{ cm}}$

$$\mu - 1 = 0.4 \quad \text{or} \quad \mu = 1.4$$

35. (b) : $\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{\Delta I_C}{\Delta I_E - \Delta I_C}$ ($\because \Delta I_E = \Delta I_B + \Delta I_C$)

or $100 = \frac{1}{\Delta I_E - 1}$

or $\Delta I_E - 1 = \frac{1}{100} = 0.01 \text{ mA}$

or $\Delta I_E = (1 + 0.01) \text{ mA} = 1.01 \text{ mA}$

36. (b) : According to Einstein's photoelectric equation

$$eV_s = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

where V_s = Stopping potential

λ = Incident wavelength

λ_0 = Threshold wavelength

or $V_s = \frac{hc}{e} \left(\frac{1}{\lambda} - \frac{1}{\lambda_0} \right)$

For the first case

$$4.8 = \frac{hc}{e} \left(\frac{1}{\lambda} - \frac{1}{\lambda_0} \right) \quad \dots (i)$$

For the second case

$$1.6 = \frac{hc}{e} \left(\frac{1}{2\lambda} - \frac{1}{\lambda_0} \right) \quad \dots (ii)$$

Divide (i) by (ii), we get

$$3 = \frac{\left(\frac{1}{\lambda} - \frac{1}{\lambda_0} \right)}{\left(\frac{1}{2\lambda} - \frac{1}{\lambda_0} \right)}$$

$$3 \left(\frac{1}{2\lambda} - \frac{1}{\lambda_0} \right) = \left(\frac{1}{\lambda} - \frac{1}{\lambda_0} \right)$$

$$\frac{3}{2\lambda} - \frac{3}{\lambda_0} = \frac{1}{\lambda} - \frac{1}{\lambda_0}$$

$$\frac{1}{2\lambda} = \frac{2}{\lambda_0} \quad \text{or} \quad \lambda_0 = 4\lambda$$

37. (c) : Work function, $\phi_0 = \frac{hc}{\lambda_{\text{longest}}}$

$$\begin{aligned} \text{or } \lambda_{\text{longest}} &= \frac{hc}{\phi_0} \\ &= \frac{(6.63 \times 10^{-34}) \times (3 \times 10^8)}{4.0 \times 1.6 \times 10^{-19}} \\ &\approx 310 \times 10^{-9} \text{ m} = 310 \text{ nm} \end{aligned}$$

38. (b) : The displacement current is given by

$$\begin{aligned} I_d &= \epsilon_0 \frac{d\phi}{dt} = \epsilon_0 \frac{d}{dt} (AE) \\ &= \frac{\epsilon_0 A}{d} \frac{dV}{dt} \quad \left(\because E = \frac{V}{d} \right) \\ I_d &= C \frac{dV}{dt} \quad \left(\because C = \frac{\epsilon_0 A}{d} \right) \end{aligned}$$

Substituting the given values, we get

$$I_d = 2 \times 10^{-6} \times 10^6 = 2 \text{ A}$$

39. (c) : $y = A \sin 2\pi \left[\frac{t}{T} - \frac{x}{\lambda} \right]$

Speed of wave = $\frac{\lambda}{T}$

Amplitude = A

Period = T

Velocity is along $+x$ -direction.

40. (b) : If F is the upward force, a is the net acceleration upward and m is the mass of each link, then

$$(5m)a = F - (5m)g \quad \text{or} \quad F = 5m(a + g) \quad \dots (i)$$

If R is the force of interaction between the top link and the one immediately below it, then

$$ma = F - mg - R$$

or $R = F - m(a + g) = 4m(a + g)$ (Using (i))

Substituting the given values we get

$$\begin{aligned} R &= 4 \times 0.1(1.2 + 9.8) \\ &= 4.4 \text{ N} \end{aligned}$$



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- If E_a be the electric field strength of a short dipole at a point on its axial line and E_e that on the equatorial line at the same distance, then
 (a) $E_e = 2E_a$ (b) $E_a = 2E_e$
 (c) $E_a = E_e$ (d) $E_a = -2E_e$
- Excitation energy of a hydrogen like ion in its first excitation state is 40.8 eV. Energy needed to remove the electron from the ion in ground state is
 (a) 54.4 eV (b) 13.6 eV
 (c) 40.8 eV (d) 27.2 eV
- Two coils have a mutual inductance 0.005 H. The current changes in the first coil according to equation $I = I_0 \sin \omega t$, where $I_0 = 10$ A and $\omega = 100\pi$ rad s^{-1} . The maximum value of emf in the second coil is (in V)
 (a) 2π (b) 5π
 (c) π (d) 4π
- Water from a tap (at the end of a horizontal pipe) emerges vertically downwards with an initial speed of 1 m s^{-1} . The cross-sectional area of the tap is 10^{-4} m^2 . Assume that the pressure is constant throughout the stream of water and the flow is steady. The cross-sectional area of the stream 0.15 m below the tap is
 (a) $5 \times 10^{-4} \text{ m}^2$ (b) $1 \times 10^{-5} \text{ m}^2$
 (c) $5 \times 10^{-5} \text{ m}^2$ (d) $2 \times 10^{-5} \text{ m}^2$
- If an average person jogs, he produces 14.5×10^3 cal per minute. This is removed by the evaporation of sweat. The amount of sweat evaporated per minute (assuming 1 kg requires 580×10^3 cal for evaporation) is
 (a) 0.025 kg (b) 2.25 kg
 (c) 0.05 kg (d) 0.20 kg
- An open pipe is suddenly closed at one end with the result that the frequency of third harmonic of the closed pipe is found to be higher by 100 Hz than fundamental frequency of the open pipe. The fundamental frequency of the open pipe is
 (a) 200 Hz (b) 300 Hz
 (c) 240 Hz (d) 480 Hz
- The escape velocity for a rocket on the Earth is 11.2 km s^{-1} . The escape velocity (in km s^{-1}) from a planet having twice the radius and same mean density is
 (a) 11.2 (b) 5.6
 (c) 15.2 (d) 22.4
- A particle is projected vertically upwards with velocity 40 m s^{-1} . What are the displacement and distance travelled by the particle in 6 s? (Take $g = 10 \text{ m s}^{-2}$)
 (a) 60 m, 80 m (b) 20 m, 60 m
 (c) 60 m, 100 m (d) 100 m, 120 m
- An 8 kg metal block of dimension $16 \text{ cm} \times 8 \text{ cm} \times 6 \text{ cm}$ is lying on a table with its face of largest area touching the table. If $g = 10 \text{ m s}^{-2}$, the minimum amount of work done in making it stand with its length vertical is
 (a) 0.4 J (b) 6.4 J
 (c) 4 J (d) 12.8 J
- Four particles each of mass m are lying symmetrically on the rim of a disc of mass M and radius R . Moment of inertia of this system about an axis passing through one of the particle and perpendicular to plane of disc is
 (a) $16mR^2$ (b) $(3M + 16m) \frac{R^2}{2}$
 (c) $(3M + 12m) \frac{R^2}{2}$ (d) zero
- Water rises to a height of 10 cm in a capillary tube and mercury falls to a depth of 3.42 cm in the same capillary tube. If the density of mercury is 13.6 g cm^{-3} and the angle of contact of mercury and water are 135° and 0° respectively, the ratio of surface tension of water and mercury is
 (a) 1 : 0.15 (b) 1 : 3
 (c) 1 : 6.5 (d) 1.5 : 1

12. At what temperature, the average kinetic energy of translatory motion of a gas molecule will be equal to that of an electron accelerated through a potential difference of 10 V?

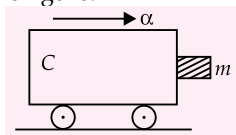
(Boltzmann constant $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$)

- (a) $2.42 \times 10^3 \text{ K}$ (b) $7.73 \times 10^3 \text{ K}$
(c) $2.42 \times 10^4 \text{ K}$ (d) $7.73 \times 10^4 \text{ K}$

13. The particle executes simple harmonic motion with a time period of 16 s. At time $t = 2 \text{ s}$, the particle crosses the mean position while at $t = 4 \text{ s}$, its velocity is 4 m s^{-1} . The amplitude of motion in m is

- (a) $\sqrt{2}\pi$ (b) $16\sqrt{2}\pi$
(c) $24\sqrt{2}\pi$ (d) $\frac{32\sqrt{2}}{\pi}$

14. A block of mass m is in contact with the cart C as shown in the figure.



The coefficient of static friction between the block and the cart is μ . The acceleration α of the cart that will prevent the block from falling satisfies

- (a) $\alpha > \frac{mg}{\mu}$ (b) $\alpha > \frac{g}{\mu m}$
(c) $\alpha \geq \frac{g}{\mu}$ (d) $\alpha < \frac{g}{\mu}$

15. A spherical planet has a mass M_p and diameter D_p . A particle of mass m falling freely near the surface of this planet will experience an acceleration due to gravity, equal to

- (a) $\frac{4GM_p}{D_p^2}$ (b) $\frac{GM_p m}{D_p^2}$
(c) $\frac{GM_p}{D_p^2}$ (d) $\frac{4GM_p m}{D_p^2}$

16. Two SHMs are represented by the equations : $y_1 = 0.1\sin(100\pi t + \pi/3)$ and $y_2 = 0.1\cos\pi t$. The initial phase difference of the velocity of particle-1 with respect to the velocity of particle-2 is

- (a) $\pi/6$ (b) $-\pi/4$
(c) $\pi/3$ (d) $-\pi/6$

17. If the change in the value of g at a height h above the surface of the Earth is the same as that at a depth x below it, when both x and h are much smaller than the radius of the Earth, then

- (a) $x = h$ (b) $x = 2h$
(c) $x = h/2$ (d) $x = h^2$

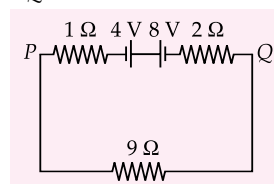
18. If a ball of steel (density $\rho = 7.8 \text{ g cm}^{-3}$) attains a terminal velocity of 10 cm s^{-1} when falling in a tank of water (coefficient of viscosity, $\eta_{\text{water}} = 8.5 \times 10^{-4} \text{ Pa s}$), then its terminal velocity in glycerine ($\rho = 1.2 \text{ g cm}^{-3}$, $\eta = 13.2 \text{ Pa s}$) would be nearly

- (a) $6.45 \times 10^{-4} \text{ cm s}^{-1}$ (b) $1.5 \times 10^{-5} \text{ cm s}^{-1}$
(c) $1.6 \times 10^{-5} \text{ cm s}^{-1}$ (d) $6.25 \times 10^{-4} \text{ cm s}^{-1}$

19. An electron is moving with the speed $5 \times 10^6 \text{ m s}^{-1}$ is shot parallel to the electric field of intensity $1 \times 10^3 \text{ N C}^{-1}$. Field is responsible for the retardation of motion of electron. Now evaluate the distance travelled by the electron before coming to rest (mass of electron $= 9 \times 10^{-31} \text{ kg}$, charge of electron $= 1.6 \times 10^{-19} \text{ C}$)

- (a) 7 m (b) 0.7 mm
(c) 7 cm (d) 0.7 cm

20. Two batteries of emf 4 V and 8 V with internal resistance 1Ω and 2Ω are connected in a circuit with a resistance of 9Ω as shown in figure. The current and potential difference between the points P and Q are



- (a) $\frac{1}{3} \text{ A}$ and 3 V (b) $\frac{1}{6} \text{ A}$ and 4 V
(c) $\frac{1}{9} \text{ A}$ and 9 V (d) $\frac{1}{2} \text{ A}$ and 12 V

21. In a common emitter amplifier, using output resistance of 5000Ω and input resistance of 2000Ω , if the peak value of input signal voltage is 10 mV and $\beta = 50$, then peak value of output voltage is

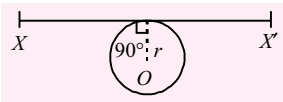
- (a) $5 \times 10^{-6} \text{ V}$ (b) $12.5 \times 10^{-4} \text{ V}$
(c) 1.25 V (d) 125 V

22. After 280 days, the activity of a radioactive sample is 6000 dps. The activity reduces to 3000 dps after another 140 days. The initial activity of the sample in dps is

- (a) 5000 (b) 9000
(c) 3000 (d) 24000

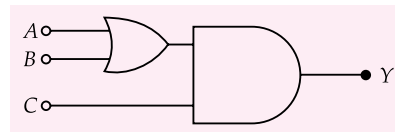
23. A convex lens is placed between object and a screen. The size of object is 3 cm and an image of height 9 cm is obtained on the screen. When the lens is displaced to a new position, what will be the size of image on the screen?

- (a) 2 cm (b) 6 cm
(c) 4 cm (d) 1 cm

24. One way in which the operation of an $n-p-n$ transistor differs from that of a $p-n-p$ transistor is that
- the emitter junction is reverse biased in the $n-p-n$
 - the emitter injects minority carriers into the base region of the $p-n-p$ and majority carriers in the base region of the $n-p-n$
 - the emitter injects holes into the base region of the $p-n-p$ and electrons into the base region of the $n-p-n$
 - the emitter injects electrons into the base region of the $p-n-p$ and holes into the base region of the $n-p-n$.
25. In Young's double slit experiment, the distance between two sources is 0.1 mm. The distance of the screen from the source is 20 cm. Wavelength of light used is 5460 \AA . The angular position of the first dark fringe is
- 0.08°
 - 0.16°
 - 0.20°
 - 0.32°
26. A particle starts from rest and has an acceleration of 2 m s^{-2} for 10 s. After that, it travels for 30 s with constant speed and then undergoes a retardation of 4 m s^{-2} and comes back to rest. The total distance covered by the particle is
- 650 m
 - 750 m
 - 700 m
 - 800 m
27. A body moves along a circular path of radius 5 m. The coefficient of friction between the surface of the path and the body is 0.5. The angular velocity in rad s^{-1} , with which the body should move so that it does not leave the path is (Take $g = 10 \text{ m s}^{-2}$)
- 4
 - 3
 - 2
 - 1
28. A thin wire of length l and uniform linear mass density ρ is bent into a circular loop with centre O and radius r as shown in figure. The moment of inertia of the loop about the axis XX' is
- 
- $\frac{3\rho l^3}{8\pi^2}$
 - $\frac{\rho l^3}{16\pi^2}$
 - $\frac{3\rho l^3}{8\pi^2 r}$
 - $\frac{\rho l^3}{8\pi^2 r}$
29. A solenoid of 0.4 m length with 500 turns carries a current of 3 A. A coil of 10 turns and of radius 0.01 m carries a current of 0.4 A. The torque

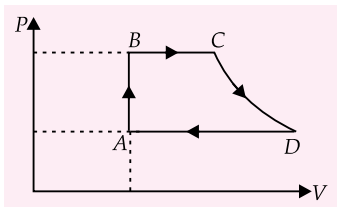
required to hold the coil with its axis at right angle to that of solenoid in the middle point of it is

- $6\pi^2 \times 10^{-7} \text{ N m}$
 - $3\pi^2 \times 10^{-7} \text{ N m}$
 - $9\pi^2 \times 10^{-7} \text{ N m}$
 - $12\pi^2 \times 10^{-7} \text{ N m}$
30. In a series resonant LCR circuit, the voltage across R is 100 V and the value of $R = 1000 \Omega$. The capacitance of the capacitor is $2 \times 10^{-6} \text{ F}$, angular frequency of ac is 200 rad s^{-1} . Then the potential difference across the inductance coil is
- 100 V
 - 40 V
 - 250 V
 - 400 V
31. The maximum wavelength of radiation that can produce photoelectric effect in certain metal is 200 nm. The maximum kinetic energy acquired by electron due to radiation of wavelength 100 nm will be
- 12.4 eV
 - 6.2 eV
 - 100 eV
 - 200 eV
32. When a hydrogen atom emits a photon in going from $n = 5$ to $n = 1$, its recoil speed is almost
- 10^{-4} m s^{-1}
 - $8 \times 10^2 \text{ m s}^{-1}$
 - $2 \times 10^{-2} \text{ m s}^{-1}$
 - 4 m s^{-1}
33. To get an output $Y = 1$ from the circuit shown in figure the inputs A, B and C must be respectively



- 1, 0, 1
 - 1, 1, 0
 - 0, 1, 0
 - 1, 0, 0
34. Two wires of same metal have the same length but their cross sections are in the ratio 3 : 1. They are joined in series. The resistance of the thicker wire is 10Ω . The total resistance of the combination is
- $\frac{5}{2} \Omega$
 - $\frac{40}{3} \Omega$
 - 40Ω
 - 100Ω
35. The equation of motion of a particle executing simple harmonic motion is $a + 16\pi^2 x = 0$. In this equation, a is the linear acceleration in m s^{-2} of the particle at a displacement x in metre. The time period of the simple harmonic motion is
- $\frac{1}{4} \text{ s}$
 - $\frac{1}{2} \text{ s}$
 - 1 s
 - 2 s
36. The speed of light (c), acceleration due to gravity (g) and pressure (P) are taken as fundamental units, the dimensions of gravitational constant (G) are
- $[c^0 g P^{-3}]$
 - $[c^2 g^3 P^{-2}]$
 - $[c^0 g^2 P^{-1}]$
 - $[c^2 g^2 P^{-2}]$

37. At a metro station, a girl walks up a stationary escalator in time t_1 . If she remains stationary on the escalator, then the escalator takes her up in time t_2 . The time taken by her to walk up on the moving escalator will be
- (a) $\frac{t_1 + t_2}{2}$ (b) $\frac{t_1 t_2}{(t_2 - t_1)}$
 (c) $\frac{t_1 t_2}{(t_2 + t_1)}$ (d) $t_1 - t_2$
38. A body of mass 60 kg is dragged with just enough force to start it moving on a rough surface with coefficients of static and kinetic frictions 0.5 and 0.4 respectively. On applying the same force, the acceleration is
- (a) 0.98 m s^{-2} (b) 9.8 m s^{-2}
 (c) 0.54 m s^{-2} (d) 5.4 m s^{-2}
39. A block of mass 0.50 kg is moving with a speed of 2.00 m s^{-1} on a smooth surface. It strikes another mass of 1.00 kg at rest and then they move as a single body. The energy loss during the collision is
- (a) 0.16 J (b) 1.00 J
 (c) 0.67 J (d) 0.34 J
40. A man stands on a rotating platform with his arms stretched holding a 5 kg weight in each hand. The angular speed of the platform is 1.2 rev s^{-1} . The moment of inertia of the man together with the platform may be taken to be constant and equal to 6 kg m^2 . If the man brings his arms close to his chest with the distance of each weight from the axis changing from 100 cm to 20 cm. The new angular speed of the platform is
- (a) 2 rev s^{-1} (b) 3 rev s^{-1}
 (c) 5 rev s^{-1} (d) 6 rev s^{-1}
41. A cycle followed by an engine (made of one mole of an ideal gas in a cylinder with a piston) is shown in figure.



The heat exchanged by the engine with the surroundings at constant volume is (Take $C_V = \frac{3}{2}R$)

- (a) $(P_B - P_A)V_A$ (b) $\frac{1}{2}(P_B - P_A)V_A$
 (c) $\frac{3}{2}(P_B - P_A)V_A$ (d) $\frac{5}{2}(P_B - P_A)V_A$

42. There are 26 tuning forks arranged in the decreasing order of their frequencies. Each tuning fork gives 3 beats with the next. The first one is octave of the last. What is the frequency of 18th tuning fork?
- (a) 100 Hz (b) 99 Hz
 (c) 96 Hz (d) 103 Hz
43. If a charged particle of charge $5 \mu\text{C}$ and mass 5 g is moving with constant speed 5 m s^{-1} in a uniform magnetic field B on a curve $x^2 + y^2 = 25$, where x and y are in metre. The value of magnetic field will be
- (a) 1 kT along x -axis (b) 1 kT along z -axis
 (c) 5 kT along the x -axis (d) 1 kT along any line in the x - y plane
44. Light of certain colour has 2000 waves to the millimetre in air. What will be the wavelength of this light in a medium of refractive index 1.25?
- (a) 1000 Å (b) 2000 Å
 (c) 3000 Å (d) 4000 Å
45. The magnifying power of a telescope is 9. When it is adjusted for parallel rays the distance between the objective and eyepiece is 20 cm. The focal length of lenses are
- (a) 10 cm, 10 cm (b) 15 cm, 5 cm
 (c) 18 cm, 2 cm (d) 11 cm, 9 cm

SOLUTIONS

1. (d): On equatorial line electric field is given by

$$\vec{E}_{\text{equatorial}} = \frac{-1}{4\pi\epsilon_0} \cdot \frac{\vec{p}}{r^3}$$

On axial line electric field is given by

$$\vec{E}_{\text{axial}} = \frac{1}{4\pi\epsilon_0} \cdot \frac{2\vec{p}}{r^3}$$

$\therefore \vec{E}_{\text{axial}} = -2\vec{E}_{\text{equatorial}}$
 Since directions are opposite.

$$\therefore E_a = -2E_e$$

2. (a): Excitation energy

$$\Delta E = E_2 - E_1 = 13.6Z^2 \left[\frac{1}{1^2} - \frac{1}{2^2} \right]$$

$$40.8 = 13.6Z^2 \times \frac{3}{4}$$

or $Z = 2$

So, energy required to remove the electron from ground state

$$= + \frac{13.6Z^2}{(1)^2} = 13.6(2)^2 = 54.4 \text{ eV}$$

3. (b): Induced emf in second coil,

$$\epsilon_2 = M \frac{dI_1}{dt} = 0.005 \times \frac{d}{dt} (I_0 \sin \omega t)$$

$$= 0.005 \times I_0 \omega \cos \omega t$$

$$\therefore \varepsilon_2|_{\max} = 0.005 \times 10 \times 100\pi = 5\pi \text{ V}$$

4. (c): Velocity of liquid after falling through a height h is given by

$$v^2 = v_0^2 + 2gh \text{ or } v = \sqrt{(1)^2 + 2(10)(0.15)}$$

$$\text{or } v = 2 \text{ m s}^{-1}$$

From equation of continuity,

$$(10^{-4} \text{ m}^2)(1 \text{ m s}^{-1}) = Av$$

$$\text{or } A = \frac{10^{-4} \text{ m}^3 \text{ s}^{-1}}{v} = \frac{10^{-4} \text{ m}^3 \text{ s}^{-1}}{2 \text{ m s}^{-1}} = 5 \times 10^{-5} \text{ m}^2$$

5. (a): Energy produces = $14.5 \times 10^3 \text{ cal min}^{-1}$.

Amount of sweat evaporated per min

$$= \frac{14.5 \times 10^3 \text{ cal min}^{-1}}{580 \times 10^3 \text{ cal kg}^{-1}} = 0.025 \text{ kg}$$

6. (a): Fundamental frequency of the open pipe,

$$v = \frac{v}{2L}$$

Frequency of the third harmonic of closed pipe,

$$v' = \frac{3v}{4L}$$

$$\text{As } v' = v + 100$$

(Given)

$$\frac{3v}{4L} = \frac{v}{2L} + 100 \text{ or } \frac{v}{4L} = 100$$

$$\text{Thus, } v = \frac{v}{2L} = 2 \times \frac{v}{4L}$$

$$= 2 \times 100 \text{ Hz} = 200 \text{ Hz}$$

7. (d): As escape velocity, $v = \sqrt{\frac{2GM}{R}}$

$$= \sqrt{\frac{2G \times (4\pi/3)R^3\rho}{R}} = \sqrt{(8\pi/3)GR^2\rho},$$

$$\therefore v \propto R\sqrt{\rho}$$

$$\text{Thus, } \frac{v_e}{v_p} = \frac{R_e\sqrt{\rho_e}}{R_p\sqrt{\rho_p}} = \frac{1}{2} \quad [\because R_p = 2R_e \text{ and } \rho_e = \rho_p]$$

$$\text{or } v_p = 2v_e = 2 \times 11.2 \text{ km s}^{-1} = 22.4 \text{ km s}^{-1}$$

8. (c): Let t_0 be the time taken by the particle to go upto the highest point, then

$$t_0 = \frac{u}{g} = \frac{40}{10} = 4 \text{ s}$$

It means, the particle will go upto the highest point in 4 s and then falls back for 2 s.

The displacement of the particle in 6 s can be calculated by using the relation

$$s = ut + \frac{1}{2}at^2$$

where $u = +40 \text{ m s}^{-1}$, $a = -10 \text{ m s}^{-2}$ and $t = 6 \text{ s}$

$$\therefore s = 40 \times 6 + \frac{1}{2}(-10) \times 6^2 = 60 \text{ m}$$

The distance travelled in 6 s is the sum of the distance travelled (s_1) in 4 s upto the highest point while going up and distance travelled (s_2) in 2 s while coming down. Therefore total distance travelled,

$$S = s_1 + s_2$$

$$= \left(ut_1 - \frac{1}{2}gt_1^2 \right) + \frac{1}{2}gt_2^2$$

$$= \left(40 \times 4 - \frac{1}{2} \times 10 \times 4^2 \right) + \frac{1}{2} \times 10 \times 2^2$$

$$= (160 - 80) + 20 = 100 \text{ m}$$

9. (c): When face of largest area is touching the table, height of centre of gravity above the table

$$= h_1 = \frac{6}{2} = 3 \text{ cm}$$

With its length vertical, height of centre of gravity

$$\text{would become } h_2 = \frac{16}{2} = 8 \text{ cm}$$

Minimum work required to be done

= Final potential energy - Initial potential energy

$$= mg(h_2 - h_1)$$

$$W = \frac{8 \times 10(8 - 3)}{100} = 4 \text{ J}$$

10. (b): According

to the theorem of parallel axis, moment of inertia of disc about

an axis passing through K and perpendicular to plane of disc as shown in figure

$$= \frac{1}{2}MR^2 + MR^2 = \frac{3}{2}MR^2$$

Total moment of inertia of the system

$$= \frac{3}{2}MR^2 + m(2R)^2 + m(\sqrt{2}R)^2 + m(\sqrt{2}R)^2$$

$$= (3M + 16m)\frac{R^2}{2}$$

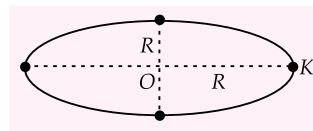
11. (c): As $h = \frac{2S \cos \theta}{r \rho g}$ or $S = \frac{hr \rho g}{2 \cos \theta}$ or $S \propto \frac{h \rho}{\cos \theta}$

Here, $h_1 = 10 \text{ cm}$, $h_2 = -3.42 \text{ cm}$

$$\theta_1 = 0^\circ, \theta_2 = 135^\circ, \rho_1 = 1 \text{ g cm}^{-3},$$

$$\rho_2 = 13.6 \text{ g cm}^{-3}$$

\therefore Ratio of surface tension of water and mercury is,



$$\begin{aligned}\frac{S_w}{S_{Hg}} &= \frac{h_1}{h_2} \times \frac{\cos \theta_2}{\cos \theta_1} \times \frac{\rho_1}{\rho_2} \\ &= \frac{10}{(-3.42)} \times \frac{\cos 135^\circ}{\cos 0^\circ} \times \frac{1}{13.6} \\ &= \frac{10}{3.42} \times \frac{0.707}{13.6} = \frac{1}{6.5}\end{aligned}$$

12. (d): Mean translational kinetic energy per molecule of a gas = $\frac{3}{2} kT$ and kinetic energy of electron when accelerated through a potential difference, V is eV .

$$\therefore eV = \frac{3}{2} kT$$

$$\begin{aligned}\text{or } T &= \frac{2eV}{3k} = \frac{2 \times (1.6 \times 10^{-19}) \times 10}{3 \times 1.38 \times 10^{-23}} \\ &= 7.73 \times 10^4 \text{ K}\end{aligned}$$

13. (d): As $y = A \sin \omega t = A \sin \frac{2\pi}{T} t$.

At $t = 2$ s, particle crosses the mean position.

\therefore After 4 s or after 2 s from mean position, velocity = 4 m s^{-1} and displacement,

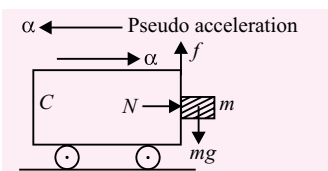
$$y_1 = A \sin \left[\frac{2\pi}{16} \times 2 \right] = A \sin \left(\frac{\pi}{4} \right) = \frac{A}{\sqrt{2}} \quad \dots(i)$$

Since, velocity = $\omega \sqrt{A^2 - y_1^2}$

$$\therefore 4 = \left(\frac{2\pi}{16} \right) \sqrt{A^2 - \frac{A^2}{2}} = \frac{\pi}{8} \times \frac{A}{\sqrt{2}}$$

$$\text{or } A = \frac{32\sqrt{2}}{\pi} \text{ m}$$

14. (c):



Pseudo force or fictitious force, $F_{\text{fic}} = m\alpha$

Force of friction, $f = \mu N = \mu m\alpha$

The block of mass m will not fall as long as

$$f \geq mg$$

$$\mu m\alpha \geq mg$$

$$\alpha \geq \frac{g}{\mu}$$

15. (a): Gravitational force acting on particle of mass m is

$$F = \frac{GM_p m}{(D_p/2)^2}$$

Acceleration due to gravity experienced by the particle is

$$g = \frac{F}{m} = \frac{GM_p}{(D_p/2)^2} = \frac{4GM_p}{D_p^2}$$

16. (d): As $y_1 = 0.1 \sin(100\pi t + \pi/3)$,

$$\therefore v_1 = \frac{dy_1}{dt} = 0.1 \times 100\pi \cos(100\pi t + \pi/3)$$

As $y_2 = 0.1 \cos \pi t = 0.1 \sin(\pi t + \pi/2)$,

$$\therefore v_2 = \frac{dy_2}{dt} = 0.1 \times \pi \cos(\pi t + \pi/2)$$

Phase difference between v_1 and v_2 at $t = 0$ is

$$\left(\frac{\pi}{3} - \frac{\pi}{2} \right) = -\frac{\pi}{6}$$

17. (b): As acceleration due to gravity at a height h ,

$$g_h = g \left(1 - \frac{2h}{R} \right),$$

acceleration due to gravity at a depth x ,

$$g_x = g \left(1 - \frac{x}{R} \right),$$

$$\text{Now, } (g - g_h) = \frac{2gh}{R} \text{ and } (g - g_x) = \frac{gx}{R}$$

For $(g - g_h) = (g - g_x)$,

$$\frac{2gh}{R} = \frac{gx}{R} \text{ or } x = 2h$$

18. (d): As terminal velocity, $v \propto \frac{(\rho - \sigma)}{\eta}$,

where ρ is density of material and σ is the density of medium.

$$\frac{v_2}{v_1} = \frac{(\rho - \sigma_2)}{\eta_2} \times \frac{\eta_1}{(\rho - \sigma_1)} = \frac{(\rho - \sigma_2)}{(\rho - \sigma_1)} \left(\frac{\eta_1}{\eta_2} \right)$$

$$\text{or } \frac{v_2}{v_1} = \frac{(7.8 - 1.2)}{(7.8 - 1)} \left(\frac{8.5 \times 10^{-4}}{13.2} \right) = \left(\frac{6.6 \times 8.5}{6.8 \times 13.2} \right) 10^{-4}$$

$$= 0.625 \times 10^{-4}$$

$$\text{Thus, } v_2 = (0.625 \times 10^{-4}) v_1 = (0.625 \times 10^{-4}) (10 \text{ cm s}^{-1}) = 6.25 \times 10^{-4} \text{ cm s}^{-1}$$

19. (c): Electric force, $qE = ma$

$$\Rightarrow a = \frac{qE}{m}$$

Here, $q = 1.6 \times 10^{-19} \text{ C}$, $E = 1 \times 10^3 \text{ N C}^{-1}$,

$$m = 9 \times 10^{-31} \text{ kg}$$

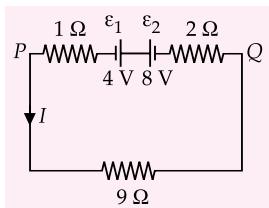
$$\therefore a = \frac{1.6 \times 10^{-19} \times 1 \times 10^3}{9 \times 10^{-31}} = \frac{1.6 \times 10^{15}}{9} \text{ m s}^{-2}$$

Speed of electron, $u = 5 \times 10^6 \text{ m s}^{-1}$ and $v = 0$

$$\text{From } v^2 = u^2 - 2as \Rightarrow s = \frac{u^2}{2a}$$

$$\therefore \text{Distance, } s = \frac{(5 \times 10^6)^2 \times 9}{2 \times 1.6 \times 10^{15}} = 7 \text{ cm}$$

20. (a):



$$\epsilon_1 = 4 \text{ V and } \epsilon_2 = 8 \text{ V}$$

As, $\epsilon_2 > \epsilon_1$ current flows from Q to P.

$$I = \frac{\text{Effectve emf}}{\text{Net Resistance}} = \frac{8 - 4}{1 + 2 + 9} = \frac{4}{12}$$

$$\therefore I = \frac{1}{3} \text{ A}$$

$$\therefore \text{Potential difference across PQ} = \frac{1}{3} \times 9 = 3 \text{ V}$$

21. (c): As voltage gain, $A_v = \frac{V_0}{V_i} = \beta \frac{R_0}{R_i}$;

$$\text{So, } V_0 = V_i \times \beta \frac{R_0}{R_i}$$

$$\text{Here, } V_i = 10 \text{ mV, } \beta = 50, R_0 = 5000 \Omega, R_i = 2000 \Omega$$

$$\therefore V_0 = 10 \times 50 \times \frac{5000}{2000} = 1250 \text{ mV} = 1.25 \text{ V}$$

22. (d): Activity reduces from 6000 dps to 3000 dps in 140 days. It implies that half life of the radioactive sample is 140 days.

In 280 days (or two half lives), activity will become

$$\frac{1}{4}^{\text{th}} \text{ of the initial activity.}$$

As the activity left is 6000 dps,

$$\therefore \text{initial activity of the sample} = 4 \times 6000 = 24000 \text{ dps.}$$

23. (d): In displacement method,

$$\text{size of object, } O = \sqrt{I_1 I_2}$$

$$\text{Here, } O = 3 \text{ cm, } I_1 = 9 \text{ cm}$$

$$\therefore 3^2 = 9 \times I_2, \text{ or } I_2 = 1 \text{ cm}$$

24. (c)

25. (b): Position of dark fringes/minima on the screen

$$\text{is given by } x = \frac{(2n-1) \lambda D}{2d},$$

where $n = 1, 2, 3, \dots$ for first, second, third... dark fringes.

For first dark fringe ($n = 1$)

$$\therefore x = (2n-1) \frac{\lambda D}{2d} = \frac{\lambda D}{2d}$$

$$\begin{aligned} \text{Angular position, } \theta &= \frac{x}{D} = \frac{\lambda}{2d} \\ &= \frac{5460 \times 10^{-10}}{2 \times 10^{-4}} \text{ radian} \end{aligned}$$

$$= 2730 \times 10^{-6} \times \frac{180}{\pi} \text{ degree} = 0.16^\circ.$$

26. (b): Distance covered in first 10 seconds

$$= \frac{1}{2} at^2 = \frac{1}{2} \times 2 \times 10^2 = 100 \text{ m} \quad (\because u = 0)$$

Velocity after 10 seconds, $v = u + at$

$$= 0 + 2 \times 10 = 20 \text{ m s}^{-1}$$

Distance covered in 30 seconds

$$= 20 \times 30 = 600 \text{ m}$$

During retardation, distance travelled

$$= \frac{v^2 - u^2}{2a} = \frac{0 - (20)^2}{2(-4)} = 50 \text{ m}$$

$$\therefore \text{Total distance} = 100 + 600 + 50 = 750 \text{ m}$$

27. (d): Here, $\mu = 0.5$

$$r = 5 \text{ m, } g = 10 \text{ m s}^{-2}$$

The frictional force provides the centripetal force

$$\therefore \frac{mv^2}{r} = \mu mg \quad \text{or} \quad v^2 = \mu rg$$

$$\begin{aligned} \text{or } v &= \sqrt{\mu rg} = \sqrt{(0.5)(5 \text{ m})(10 \text{ m s}^{-2})} \\ &= 5 \text{ m s}^{-1} \end{aligned}$$

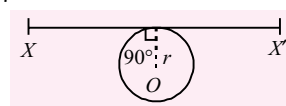
$$\text{As } v = r\omega \quad \text{or} \quad \omega = \frac{v}{r} = \frac{5 \text{ m s}^{-1}}{5 \text{ m}} = 1 \text{ rad s}^{-1}$$

28. (a): Since $2\pi r = l$, $r = l/2\pi$

... (i)

Mass, $M = \rho l$

... (ii)



Moment of inertia of the loop about the axis XX'

= moment of inertia about its diameter + Mr^2
(by theorem of parallel axes)

$$= \frac{Mr^2}{2} + Mr^2 = \frac{3}{2} Mr^2 = \frac{3}{2} (\rho l) \left(\frac{l}{2\pi} \right)^2$$

[Using (i) and (ii)]

$$= \frac{3\rho l^3}{8\pi^2}$$

29. (a): Magnetic field for solenoid, $B =$

$$\mu_0 n I = 4\pi \times 10^{-7} \times \frac{500}{0.4} \times 3 \text{ T}$$

Magnetic moment of the coil = $I \times A \times N$

$$M = 0.4 \times \pi \times (0.01)^2 \times 10 \text{ A m}^2$$

$$\tau = MB \sin \theta$$

$$\text{Here, } \theta = 90^\circ, \sin 90^\circ = 1$$

$$\therefore \tau = 0.4 \times \pi \times (0.01)^2 \times 10 \times 4\pi \times 10^{-7} \times \frac{500}{0.4} \times 3$$

$$= 6\pi^2 \times 10^{-7} \text{ N m}$$

30. (c): Here, $V_R = 100 \text{ V, } R = 1000 \Omega$

$$C = 2 \times 10^{-6} \text{ F, } \omega = 200 \text{ rad s}^{-1}$$

The current in the circuit is

$$I = \frac{V_R}{R} = \frac{100 \text{ V}}{1000 \Omega} = 0.1 \text{ A}$$

At resonance,

$$V_L = V_C = IX_C = \frac{I}{\omega C}$$

$$= \frac{0.1}{200 \times 2 \times 10^{-6}} = \frac{1000}{4} = 250 \text{ V}$$

31. (b): Here, $\lambda_0 = 200 \text{ nm}$, $\lambda = 100 \text{ nm}$,

$$\frac{hc}{e} = 1240 \text{ eV nm}$$

$$\text{Maximum kinetic energy} = \frac{hc}{\lambda e} - \frac{hc}{\lambda_0 e} \text{ (in eV)}$$

$$= \frac{hc}{e} \left(\frac{1}{\lambda} - \frac{1}{\lambda_0} \right)$$

$$= 1240 \left(\frac{1}{100} - \frac{1}{200} \right)$$

$$= 6.2 \text{ eV}$$

32. (d): Energy of photon emitted,

$$E = 13.6 \left(\frac{1}{1^2} - \frac{1}{5^2} \right) \text{ eV} = 13.6 \times \frac{24}{25} \text{ eV} = 13.06 \text{ eV}$$

$$\text{Momentum of photon} = \frac{E}{c}$$

The momentum of hydrogen atom is equal and opposite to the momentum of photon. If m is the mass of hydrogen atom ($= 1.67 \times 10^{-27} \text{ kg}$) and v is recoil speed of hydrogen atom, then

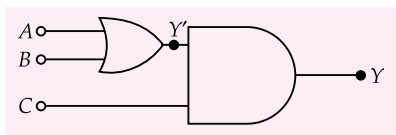
$$mv = \frac{E}{c}$$

$$v = \frac{E}{mc} = \frac{13.06 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27} \times 3 \times 10^8}$$

$$v = 4.17 \text{ m s}^{-1} \approx 4 \text{ m s}^{-1}$$

33. (a): The output of OR gate is

$$Y' = (A + B)$$



The output of AND gate is

$$Y = Y' \cdot C = (A + B) \cdot C$$

If $A = 1$, $B = 0$, $C = 1$, then $Y = (1 + 0) \cdot 1 = 1$

34. (c): For the same length and same material,

$$\frac{R_2}{R_1} = \frac{A_1}{A_2} = \frac{3}{1} \text{ or } R_2 = 3R_1$$

The resistance of thick wire, $R_1 = 10 \Omega$

The resistance of thin wire $= 3R_1 = 3 \times 10 = 30 \Omega$

Total resistance $= 10 + 30 = 40 \Omega$

35. (b): The given equation of SHM is

$$a = -16\pi^2 x \quad \dots(i)$$

Acceleration in standard equation of SHM is

$$a = -\omega^2 x \quad \dots(ii)$$

Comparing equations (i) and (ii), we get

$$\omega^2 = 16\pi^2 \text{ or } \omega = 4\pi$$

$$\therefore T = \frac{2\pi}{\omega} = \frac{2\pi}{4\pi} = \frac{1}{2} \text{ s}$$

36. (c): Let $G = kc^x g^y P^z$

$$[M^{-1}L^3T^{-2}] = [LT^{-1}]^x [LT^{-2}]^y [ML^{-1}T^{-2}]^z$$

$$= [M^z L^{x+y-2z} T^{-x-2y-2z}]$$

Equating both sides, we get,

$$z = -1, x + y - z = 3, -x - 2y - 2z = -2$$

On solving, $x = 0$, $y = 2$, $z = -1$.

$$\text{Thus, } [G] = [c^0 g^2 P^{-1}]$$

37. (c): Let l be the length of escalator, v_g be the velocity of the girl (relative to stationary escalator) and v_e that of escalator (relative to ground).

$$\text{Clearly, } t_1 = \frac{l}{v_g} \text{ and } t_2 = \frac{l}{v_e} \quad \dots(i)$$

When the girl walks on the moving escalator, her velocity relative to the ground is $(v_e + v_g)$.

If t is the time taken by the girl to move a distance l on the escalator relative to ground, then

$$t = \frac{l}{v_g + v_e} \text{ or } \frac{1}{t} = \frac{v_g}{l} + \frac{v_e}{l} \quad \dots(ii)$$

$$\text{From equations (i) and (ii), } \frac{1}{t} = \frac{1}{t_1} + \frac{1}{t_2} = \frac{t_2 + t_1}{t_1 t_2}$$

$$\text{or } t = \frac{t_1 t_2}{(t_2 + t_1)}$$

38. (a): $f_s = \mu_s R$ and $f_k = \mu_k R$

When the body is in motion, net force acting on the body,

$$\text{i.e., } F = f_s - f_k = \mu_s R - \mu_k R$$

$$\text{or } a = \frac{F}{m} = \frac{(\mu_s - \mu_k)mg}{m} \quad (\because R = mg)$$

$$= (\mu_s - \mu_k)g$$

$$= (0.5 - 0.4) \times 9.8 = 0.98 \text{ m s}^{-2}.$$

39. (c): By conservation of momentum

$$0.5 \times 2 + 1 \times 0 = (0.5 + 1)v = 1.5 v,$$

$$\therefore v = \frac{2}{3} \text{ m s}^{-1} = 0.67 \text{ m s}^{-1}$$

$$\text{Energy loss} = K_i - K_f = \frac{1}{2} (0.5)(2)^2 - \frac{1}{2} (1.5)(0.67)^2$$

$$= 1 \text{ J} - 0.33 \text{ J}$$

$$= 0.67 \text{ J}$$

40. (b): Initial moment of inertia,

$$I_1 = 6 + 2 \times 5 \times (1)^2 = 16 \text{ kg m}^2$$

Initial angular velocity, $\omega_1 = 1.2 \text{ rev s}^{-1}$

Initial angular momentum is

$$L_1 = I_1 \omega_1$$

Final moment of inertia,

$$I_2 = 6 + 2 \times 5 \times (0.2)^2 = 6.4 \text{ kg m}^2$$

Final angular speed = ω_2

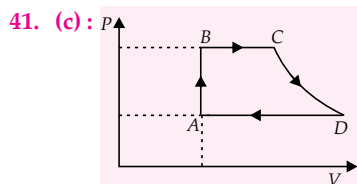
Final angular momentum is

$$L_2 = I_2 \omega_2$$

According to law of conservation of angular momentum,

$$L_1 = L_2 \text{ or } I_1 \omega_1 = I_2 \omega_2$$

$$\omega_2 = \frac{I_1 \omega_1}{I_2} = \frac{(16 \text{ kg m}^2)(1.2 \text{ rev s}^{-1})}{(6.4 \text{ kg m}^2)} = 3 \text{ rev s}^{-1}$$



In the given figure, portion AB of the cycle shows increase in pressure/temperature of gas at constant volume.

Therefore system gains heat from the surroundings, then

$$Q_{AB} = U_{AB} = nC_V \Delta T$$

$$Q_{AB} = 1 \times C_V \times \Delta T = \frac{3}{2} R(T_B - T_A) = \frac{3}{2} (P_B V_B - P_A V_A)$$

$$\therefore Q_{AB} = \frac{3}{2} (P_B - P_A) V_A \quad (\because V_A = V_B)$$

42. (b): Let the frequency of first tuning fork is ν .

The frequencies of other tuning forks are

$$(\nu - 3), (\nu - 2 \times 3), \dots, (\nu - 17 \times 3), \dots, (\nu - 25 \times 3).$$

As per given condition,

$$\nu = 2(\nu - 25 \times 3) \text{ or } \nu = 2\nu - 25 \times 6$$

$$\text{or } \nu = 25 \times 6 = 150 \text{ Hz}$$

The frequency of the 18th tuning fork

$$= \nu - 17 \times 3 = 150 - 51 = 99 \text{ Hz.}$$

43. (b): $x^2 + y^2 = 25$

$$\therefore r = 5 \text{ m}$$

$$\therefore r = \frac{mv}{qB} \text{ or } 5 = \frac{5 \times 10^{-3} \times 5}{5 \times 10^{-6} \times B}$$

$$\therefore B = \frac{5 \times 10^{-3} \times 5}{5 \times 10^{-6} \times 5} = 10^3 \text{ T} = 1 \text{ kT}$$

The magnetic field will be 1 kT along z-axis.

44. (d): $\lambda_{\text{air}} = \frac{1 \text{ mm}}{2000}$

$$= 5 \times 10^{-4} \text{ mm} = 5 \times 10^{-7} \text{ m} = 5000 \text{ \AA}$$

$$\lambda_{\text{medium}} = \frac{\lambda_{\text{air}}}{\mu} = \frac{5000 \text{ \AA}}{1.25} = 4000 \text{ \AA}$$

45. (c): Magnifying power, $m = \frac{f_o}{f_e} = 9 \dots(i)$

where f_o and f_e are the focal lengths of the objective and eyepiece respectively

$$\text{Also, } f_o + f_e = 20 \text{ cm} \dots(ii)$$

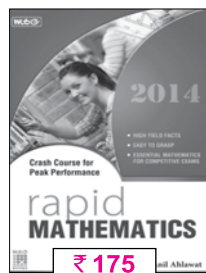
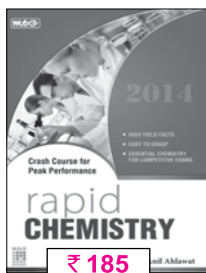
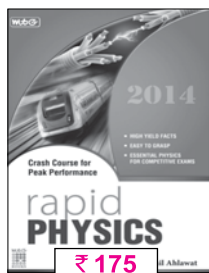
On solving (i) and (ii), we get

$$f_o = 18 \text{ cm, } f_e = 2 \text{ cm}$$

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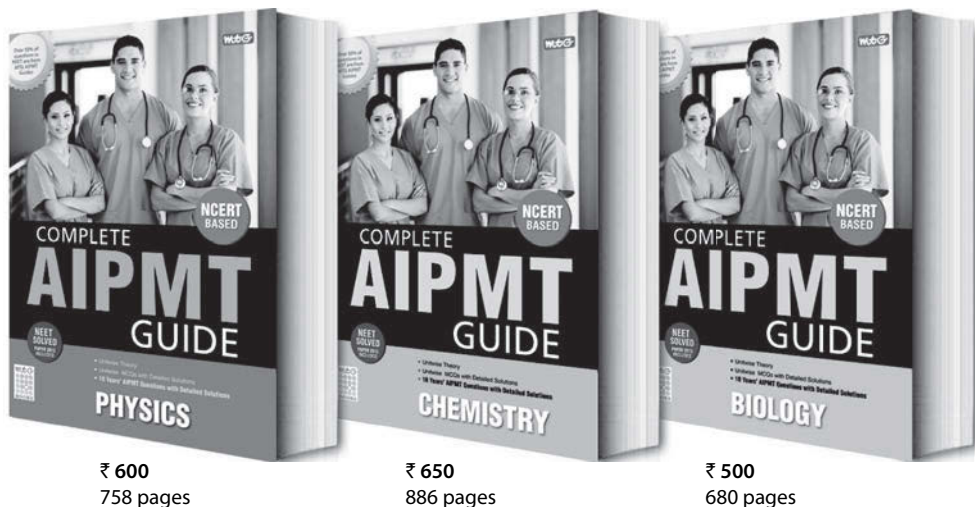
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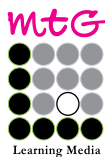
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CLASS XII

GENERAL INSTRUCTIONS

- All questions are compulsory.
- There are 30 questions in total. Questions Nos. 1 to 8 are very short answer type questions and carry one mark each.
- Questions Nos. 9 to 18 carry two marks each. Questions Nos. 19 to 27 carry three marks each and questions Nos. 28 to 30 carry five marks each.
- One of the questions carrying three marks weightage is value based question.
- There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all three questions of five marks each weightage. You have to attempt only one of the choices in such questions.
- Use of calculators is not permitted. However, you may use log tables if necessary.
- You may use the following values of physical constants wherever necessary :

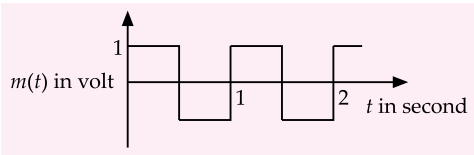
$$c = 3 \times 10^8 \text{ m s}^{-1}, h = 6.63 \times 10^{-34} \text{ J s}, e = 1.6 \times 10^{-19} \text{ C},$$

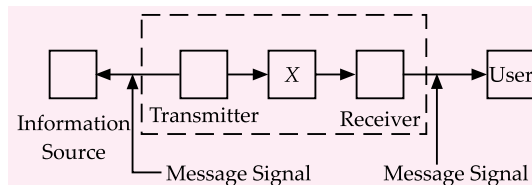
$$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}, \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}, m_e = 9.1 \times 10^{-31} \text{ kg}$$

- Define the term 'Mobility' of charge carriers in a conductor. Write its S.I. unit.
- The carrier wave is given by

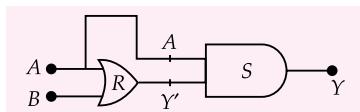
$$C(t) = 2 \sin(8\pi t) \text{ volt.}$$

The modulating signal is a square wave as shown. Find modulation index.


- "For any charge configuration, equipotential surface through a point is normal to the electric field." Justify.
- Two spherical bobs, one metallic and the other of glass, of the same size are allowed to fall freely from the same height above the ground. Which of the two would reach earlier and why?
- Show variation of resistivity of copper as a function of temperature in a graph.
- A convex lens is placed in contact with a plane mirror. A point object at a distance of 20 cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens?
- Write the expression, in a vector form, for the Lorentz magnetic force \vec{F} due to a charge moving with velocity \vec{V} in a magnetic field \vec{B} . What is the direction of the magnetic force?
- The figure given below shows the block diagram of a generalized communication system. Identify the element labelled 'X' and write its function.

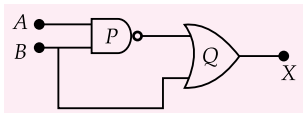


9. Out of the two magnetic materials, 'A' has relative permeability slightly greater than unity while 'B' has less than unity. Identify the nature of the materials 'A' and 'B'. Will their susceptibilities be positive or negative?
10. Given a uniform electric field $\vec{E} = 5 \times 10^3 \hat{i}$ N/C find the flux of this field through a square of 10 cm on a side whose plane is parallel to the y - z plane. What would be the flux through the same square if the plane makes a 30° angle with the x -axis.
11. For a single slit of width ' a ', the first minimum of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of $\frac{\lambda}{a}$. At the same angle of $\frac{\lambda}{a}$, we get a maximum for two narrow slits separated by a distance ' a '. Explain
12. Write the truth table for the combination of the gates shown. Name the gates used.

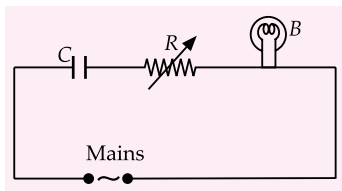


OR

Identify the logic gates marked 'P' and 'Q' in the given circuit. Write the truth table for the combination.



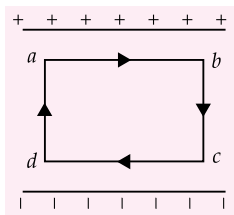
13. State Kirchhoff's rules. Explain briefly how these rules are justified.
14. A capacitor ' C ', a variable resistor ' R ' and a bulb ' B ' are connected in series to the ac mains in circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same; (ii) the resistance R is increased keeping the same capacitance?



15. State the underlying principle of a cyclotron. Write briefly how this machine is used to accelerate charged particles to high energies.
16. An electric dipole of length 4 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $4\sqrt{3}$ N m. Calculate the potential energy of the dipole, if it has charge ± 8 nC.
17. A proton and a deuteron are accelerated through the same accelerating potential. Which one of the two has
(a) greater value of de-Broglie wavelength associated with it, and
(b) less momentum?
Give reasons to justify your answer.
18. (i) Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2.0×10^{-3} W. Estimate the number of photons emitted per second on an average by the source.
(ii) Draw a plot showing the variation of photoelectric current versus the intensity of incident radiation on a given photosensitive surface.
19. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. Up to which energy level the hydrogen atoms would be excited?
Calculate the wavelengths of the first member of Lyman and first member of Balmer series.
20. When Sunita, a class XII student, came to know that her parents are planning to rent out the top floor of their house to a mobile company she protested. She tried hard to convince her parents that this move would be a health hazard. Ultimately her parents agreed :
(i) In what way can the setting up of transmission tower by a mobile company in a residential colony prove to be injurious to health?
(ii) By objecting to this move of her parents, what value did Sunita display?
(iii) Estimate the range of e.m. waves which can be transmitted by an antenna of height 20 m. (Given radius of the earth = 6400 km)
21. A potentiometer wire of length 1 m has a resistance of 10Ω . It is connected to a 6 V battery in series with a resistance of 5Ω . Determine the emf of the primary cell which gives a balance point at 40 cm.
22. (a) Draw a labelled ray diagram showing the formation of a final image by a compound microscope at least distance of distinct vision.

- (b) The total magnification produced by a compound microscope is 20. The magnification produced by the eye piece is 5. The microscope is focussed on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If least distance of distinct vision is 20 cm, calculate the focal length of the objective and the eye piece.

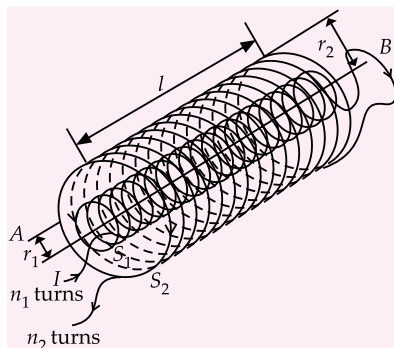
23. (a) A mobile phone lies along the principal axis of a concave mirror. Show, with the help of a suitable diagram, the formation of its image. Explain why magnification is not uniform.
- (b) Suppose the lower half of the concave mirror's reflecting surface is covered with an opaque material. What effect this will have on the image of the object? Explain.
24. (a) Obtain the expression for the energy stored per unit volume in a charged parallel plate capacitor.
- (b) The electric field inside a parallel plate capacitor is E . Find the amount of work done in moving a charge q over a closed rectangular loop $a b c d a$.



OR

- (a) Derive the expression for the capacitance of a parallel plate capacitor having plate area A and plate separation d .
- (b) Two charged spherical conductors of radii R_1 and R_2 when connected by a conducting wire acquire charges q_1 and q_2 respectively. Find the ratio of their surface charge densities in terms of their radii.
25. (a) State Ampere's circuital law, expressing it in the integral form.
- (b) Two long coaxial insulated solenoids, S_1 and S_2 of equal lengths are wound one over the other as shown in the figure. A steady current " I " flow through the inner solenoids S_1 to the other end B , which is connected to the outer solenoid S_2 through which the same current " I " flows in the opposite direction so as to come out at end A . If n_1 and n_2 are the number of turns per unit length, find the magnitude

and direction of the net magnetic field at a point (i) inside on the axis and (ii) outside the combined system.



26. Answer the following questions:
- (a) Name the em waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves.
- (b) If the Earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.
- (c) An em wave exerts pressure on the surface on which it is incident. Justify.
27. (a) Deduce the expression, $N = N_0 e^{-\lambda t}$, for the law of radioactive decay.
- (b) (i) Write symbolically the process expressing the β^+ decay of ${}^{22}_{11}\text{Na}$. Also write the basic nuclear process underlying this decay.
- (ii) Is the nucleus formed in the decay of the nucleus ${}^{22}_{11}\text{Na}$, an isotope or isobar?
28. (a) (i) Two independent monochromatic sources of light cannot produce a sustained interference pattern'. Give reason.
- (ii) Light waves each of amplitude " a " and frequency " ω ", emanating from two coherent light sources superpose at a point. If the displacements due to these waves is given by $y_1 = a \cos \omega t$ and $y_2 = a \cos(\omega t + \phi)$ where ϕ is the phase difference between the two, obtain the expression for the resultant intensity at the point.
- (b) In Young's double slit experiment, using monochromatic light of wavelength λ , the intensity of light at a point on the screen where path difference is λ , is K units. Find out the intensity of light at a point where path difference is $\lambda/3$.

OR

- (a) How does one demonstrate, using a suitable diagram, that unpolarised light when passed through a Polaroid gets polarised?
- (b) A beam of unpolarised light is incident on a glass-air interface. Show, using a suitable ray diagram, that light reflected from the interface is totally polarised, when $\mu = \tan i_B$ where μ is the refractive index of glass with respect to air and i_B is the Brewster's angle.

29. (a) Describe a simple experiment (or activity) to show that the polarity of emf induced in a coil is always such that it tends to produce a current which opposes the change of magnetic flux that produces it.
- (b) The current flowing through an inductor of self inductance L is continuously increasing. Plot a graph showing the variation of
- Magnetic flux versus the current
 - Induced emf versus dI/dt
 - Magnetic potential energy stored versus the current

OR

- (a) Draw a schematic sketch of an ac generator describing its basic elements. State briefly its working principle. Show a plot of variation of
- Magnetic flux and
 - Alternating emf versus time generated by a loop of wire rotating in a magnetic field.
- (b) Why is choke coil needed in the use of fluorescent tubes with ac mains?

30. (a) State briefly the processes involved in the formation of p - n junction explaining clearly how the depletion region is formed.
- (b) Using the necessary circuit diagrams, show how the V-I characteristics of a p - n junction are obtained in
- Forward biasing
 - Reverse biasing

How are these characteristics made use of in rectification.

OR

- (a) Differentiate between segments of a transistor on the basis of their size and level of doping.
- (b) How is transistor biased to be in active state?
- (c) With the help of necessary circuit diagram, describe briefly how n - p - n transistor in CE configuration amplifies a small sinusoidal input voltage. Write the expression for the ac current gain.

SOLUTIONS

1. **Mobility** : It is defined as drift velocity per unit electric field.

$$\text{i.e., } \mu = \frac{v}{E}$$

SI unit of $\mu = \text{m}^2 \text{V}^{-1} \text{s}^{-1}$.

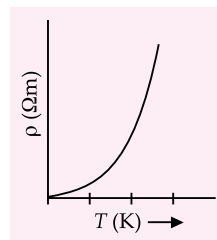
2. Modulation index,

$$\mu = \frac{\text{Amplitude of modulated signal } (A_m)}{\text{Amplitude of carries wave } (A_c)}$$

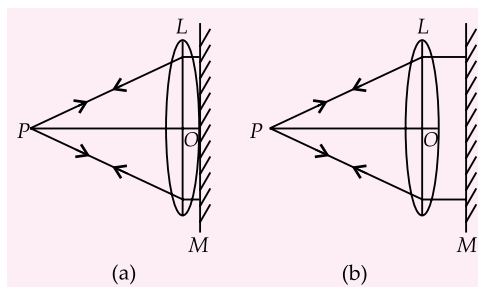
Here, $A_m = 1 \text{ m}$, $A_c = 2 \text{ m}$

$$\therefore \mu = \frac{1}{2} = 0.5$$

3. If the field were not normal to the equipotential surface, it would have a non zero component along the surface. So to move a test charge against this component, a work would have to be done. But there is no potential difference between any two points on an equipotential surface and consequently no work is required to move a test charge on the surface. Hence the electric field must be normal to the equipotential surface at every point.
4. As the glass bob is non-metallic, so it will reach the ground earlier than the metallic bob. As the metallic bob falls, it intercepts Earth's magnetic field and induced currents are set in it which oppose its downward motion. No such currents are induced in case of non-metallic bob.
5. The variation of resistivity of copper with temperature as shown in figure.



- 6.



From figure, focal length of lens,
 $= OP = 20 \text{ cm}$

7. The magnetic force experienced by the charge q moving with velocity \vec{V} in magnetic field \vec{B} is given by Lorentz force, $\vec{F} = q(\vec{V} \times \vec{B})$. The direction of the Lorentz force is perpendicular to the plane containing \vec{V} and \vec{B} . Its direction is given by right-handed screw rule.

8. X in given diagram represents the communication channel. It carries the modulated wave from the transmitter to the receiver.

9. If the relative permeability is greater than unity i.e. $\mu_r > 1$, then the material is paramagnetic material. Hence, 'A' is paramagnetic material and its susceptibility is positive. If relative permeability is less than unity i.e. $\mu_r < 1$, then the material is diamagnetic material. Hence, 'B' is diamagnetic material and its susceptibility is negative.

10. Here, $\vec{E} = 5 \times 10^3 \text{ N/C}$
Side of square $= a = 10 \text{ cm} = 0.1 \text{ m}$
Area of square, $S = a^2 = (0.1)^2 = 0.01 \text{ m}^2$

Case I : Area vector is along x-axis,

$$\vec{S} = 0.01 \hat{i} \text{ m}^2$$

$$\text{Required flux, } \phi = \vec{E} \cdot \vec{S}$$

$$\Rightarrow \phi = (5 \times 10^3 \hat{i}) \cdot (0.01 \hat{i})$$

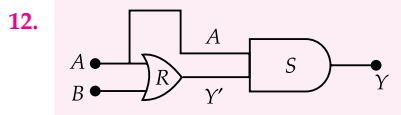
$$\Rightarrow \phi = 50 \text{ N m}^2/\text{C}$$

Case II : Plane of the square makes a 30° angle with the x-axis.

Here, angle between area vector and the electric field is 60° .

$$\begin{aligned} \text{So, required flux, } \phi' &= E \cdot S \cos \theta \\ &= (5 \times 10^3)(0.01) \cos 60^\circ \\ &= 25 \text{ N m}^2/\text{C} \end{aligned}$$

11. For a single slit of width "a" the first minima of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of (λ/a) because the light from centre of the slit differs by a half of a wavelength. Whereas a double slit experiment at the same angle of (λ/a) and slits separation "a" produces maxima because one wavelength difference in path length from these two slits is produced.



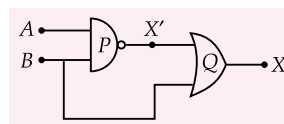
Here, R represents OR gate and S represents AND gate

The output Y of the given combination of gates
 $Y = Y'A$

Truth table for the given combination

| A | B | $Y' = A + B$ | $Y = Y'A$ |
|---|---|--------------|-----------|
| 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 1 | 1 |

OR



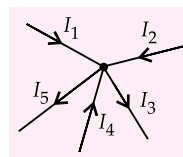
Here, P represents NAND gate and Q represents OR gate.

The output X of the given combination of gates
 $X = (B + X')$

Truth table for given combination

| A | B | $X' = \overline{AB}$ | $X = (B + X')$ |
|---|---|----------------------|----------------|
| 0 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 |

13. **Kirchhoff's first rule :** The algebraic sum of all the current passing through a junction of an electric circuit is zero.



Here, I_1, I_2, I_3, I_4 and I_5 are current in different branches of a circuit which meet at a junction.

$$I_1 + I_2 - I_3 + I_4 - I_5 = 0$$

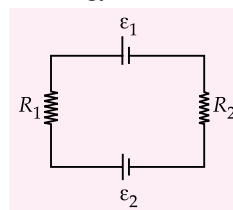
This rule is based on the principle of conservation of charge.

Kirchhoff's second rule : The algebraic sum of the applied emf's of an electrical circuit is equal to the algebraic sum of potential drops across the resistors of the loop.

Mathematically,

$$\Sigma \varepsilon = \Sigma IR$$

This is based on energy conservation principle



Using this rule,

$$\varepsilon_1 - \varepsilon_2 = IR_1 + IR_2$$

14. For the RC circuit,

$$\text{Impedance, } Z = \sqrt{R^2 + (1/\omega C)^2}$$

$$\text{Current, } I = \frac{\varepsilon_0}{Z} \quad \dots (i)$$

Case I : When a dielectric slab is introduced between the plates of the capacitor, then its capacitance increases. Hence, from equation (i), impedance of the circuit is decreased and the current through it is increased. So, brightness of the bulb will increase.

Case II : The resistance R is increased and capacitance is same. Hence, from equation (i), impedance of the circuit is increased and the current flowing through it is decreased. So, brightness of the bulb will decrease.

15. Refer point 3.3-5 page no. 157 (MTG Excel in Physics).

16. Given,

Length of electric dipole, $l = 4 \text{ cm} = 0.04 \text{ m}$

Charge, $q = \pm 8 \text{ nC} = \pm 8 \times 10^9 \text{ C}$

Torque, $= 4\sqrt{3} \text{ N m}$, $\theta = 60^\circ$

Potential energy, $U = ?$

$$\text{As } \tau = pE \sin \theta \quad \dots (i)$$

$$U = -pE \cos \theta \quad \dots (ii)$$

Dividing equation (ii) by (i), we get

$$\frac{U}{\tau} = \frac{-pE \cos \theta}{pE \sin \theta} = -\cot \theta$$

$$\Rightarrow U = -\tau \cot \theta$$

$$\Rightarrow U = -(4\sqrt{3}) \cot 60^\circ = -4\sqrt{3} \times \frac{1}{\sqrt{3}}$$

$$\Rightarrow U = -4 \text{ J}$$

17. For same accelerating potential, a proton and a deuteron have same kinetic energy.

(a) de-Broglie wavelength is given by

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2m(qV)}}$$

$$\text{So, } \lambda \propto \frac{1}{\sqrt{m}}$$

Mass of a deuteron is more than that of a proton. So, proton will have greater value of de-Broglie wavelength.

(b) Momentum, $p = \sqrt{2mK}$

$$p \propto \sqrt{m}$$

Mass of a deuteron is more than that of a proton. So, a proton has less momentum.

18. (i) Given,
 $\nu = 6.0 \times 10^{14} \text{ Hz}$
 $p = 2.0 \times 10^{-3} \text{ W}$

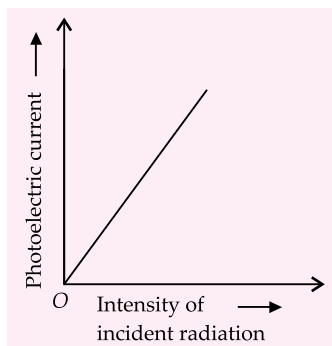
Let n is the number of photons emitted by the source per second.

$$n = \frac{p}{E} = \frac{p}{h\nu}$$

$$= \frac{2 \times 10^{-3}}{6.63 \times 10^{-34} \times (6.0 \times 10^{14})} = 0.0502 \times 10^{17}$$

$$= 5 \times 10^{15} \text{ photons per second.}$$

(ii)



19. Here, $\Delta E = 12.5 \text{ eV}$
 Energy of an electron in n^{th} orbit of hydrogen atom is,

$$E_n = -\frac{13.6}{n^2} \text{ eV}$$

In ground state, $n = 1$

$$E_1 = -13.6 \text{ eV}$$

Energy of an electron in the excited state after absorbing a photon of 12.5 eV energy will be

$$E_n = -13.6 + 12.5 = -1.1 \text{ eV}$$

$$\therefore n^2 = \frac{-13.6}{E_n} = \frac{-13.6}{-1.1} = 12.36$$

$$\Rightarrow n = 3.5$$

Here, state of electron cannot be fraction,

So, $n = 3$

The wavelength λ of the first member of Lyman series is given by

$$\frac{1}{\lambda} = R \left[\frac{1}{1^2} - \frac{1}{2^2} \right] = \frac{3}{4} R$$

$$\Rightarrow \lambda = \frac{4}{3R} = \frac{4}{3 \times 1.097 \times 10^7}$$

$$\Rightarrow \lambda = 1.215 \times 10^{-7} \text{ m}$$

$$\Rightarrow \lambda = 121 \times 10^{-9} \text{ m}$$

$$\Rightarrow \lambda = 121 \text{ nm}$$

The wavelength λ' of the first member of the Balmer series is given by

$$\frac{1}{\lambda'} = R \left[\frac{1}{2^2} - \frac{1}{3^2} \right] = \frac{5}{36} R$$

$$\Rightarrow \lambda' = \frac{36}{5R} = \frac{36}{5 \times (1.097 \times 10^7)}$$

$$= 6.56 \times 10^{-7} \text{ m}$$

$$= 656 \times 10^{-9} \text{ m}$$

$$= 656 \text{ nm}$$

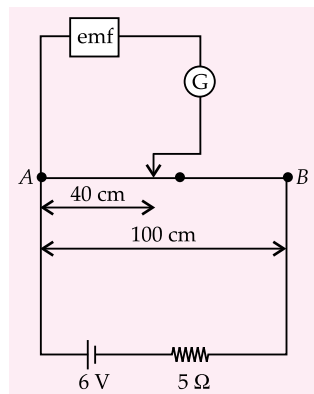
20. (i) A transmission tower transmits electromagnetic waves such as microwaves, exposure to these waves can cause severe health hazards like cancer and tumour. Also transmission tower (antenna) works on a very high power, so the risk of someone severely gets burnt increased in residential area.

(ii) Sunita has displayed awareness towards the health and environment of society by objecting to this move of her parents.

(iii) Here, $R = 6400 \text{ km} = 64 \times 10^5 \text{ m}$; $h = 20 \text{ m}$, $d = ?$
Range of the transmitting antenna,

$$\begin{aligned} d &= \sqrt{2hR} \\ &= \sqrt{2 \times (20) \times (64 \times 10^5)} \\ &= \sqrt{4 \times 64 \times 10^6} \\ \Rightarrow d &= 16000 \text{ m} \end{aligned}$$

21.



Net resistance of the circuit,
 $R = (R_{AB} + 5) = 10 + 5 = 15 \Omega$
Current flowing in the circuit,

$$I = \frac{V}{R} = \frac{6}{15} \text{ A}$$

Potential drop across $AB = IR_{AB}$
 $= \frac{6}{15} \times 10 = 4 \text{ V}$

e.m.f. of primary cell, $\varepsilon = \frac{l}{L} V_{AB}$

Here, $l = 40 \text{ cm}$, $L = 100 \text{ cm}$, $V_{AB} = 4 \text{ V}$

So, $\varepsilon = \frac{40}{100} \times 4 = 1.6 \text{ V}$

22. (a) Refer point 6.9-2 page no. 347 (MTG Excel in Physics).

(b) Separation between eye-piece and the objective,
 $L = 14 \text{ cm}$,

$m = -20$, $m_e = 5$, $D = 20 \text{ cm}$, $f_o = ?$, $f_e = ?$

Magnification of eye-piece when image is formed at the least distance for clear vision

$$m_e = \left(1 + \frac{D}{f_e}\right)$$

$$\Rightarrow 5 = \left(1 + \frac{20}{f_e}\right)$$

$$\Rightarrow 4 = \frac{20}{f_e}$$

$$\Rightarrow f_e = 5 \text{ cm}$$

Net magnification of the compound microscope when image is formed at the least distance for clear vision

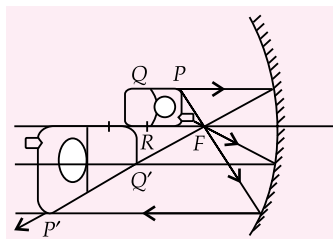
$$m = -\frac{L}{f_o} \left(1 + \frac{D}{f_e}\right)$$

$$\Rightarrow -20 = -\frac{14}{f_o} \left(1 + \frac{20}{5}\right)$$

$$\Rightarrow 10 = \frac{7}{f_o} (5)$$

$$\Rightarrow f_o = \frac{35}{10} = 3.5 \text{ cm}$$

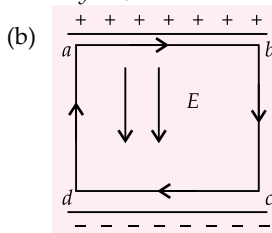
23.



The formation of the image of the cell phone is shown in fig. The part which is at R will be imaged at R and will be of the same size, i.e., $Q'R = QR$. The other end P of the mobile phone is highly magnified by the concave mirror. Thus the different parts of the mobile phone are magnified in different proportions because of their different locations from the concave mirror.

(b) At first sight, it appears that the image will be half of the object, but taking the laws of reflection to be true for all points of the mirror the image will be of the whole object. However, as the area of the reflecting surface has reduced, the intensity of the image will be low.

24. (a) Refer point 1.11 page no. 16 (MTG Excel in Physics).



Electric field inside a parallel plate capacitor $= E$
Here, electric field is conservative. Work done by the conservative force in closed loop is zero.

So, required work done = 0

OR

(a) Refer point 1.11-4 page no. 15 (MTG Excel in Physics).

(b) Surface charge density,

$$\sigma = \frac{\text{Net charge } (q)}{\text{Surface area } (A)}$$

For spherical conductor of radius, R_1

$$\sigma_1 = \frac{q_1}{4\pi R_1^2} \quad \dots (i)$$

For spherical conductor of radius, R_2

$$\sigma_2 = \frac{q_2}{4\pi R_2^2} \quad \dots (ii)$$

Also, $q = CV$; $V_1 = V_2$

[as they are connected through conducting wire.]

So, $q \propto C$

$$\frac{q_1}{q_2} = \frac{4\pi R_1}{4\pi R_2}$$

$$\Rightarrow \frac{q_1}{q_2} = \frac{R_1}{R_2}$$

Dividing equation (i) by (ii), we get

$$\frac{\sigma_1}{\sigma_2} = \frac{\frac{q_1}{4\pi R_1^2}}{\frac{q_2}{4\pi R_2^2}} = \frac{q_1}{q_2} \times \frac{R_2^2}{R_1^2} = \frac{R_1}{R_2} \times \frac{R_2^2}{R_1^2} = \frac{R_2}{R_1}$$

$$\Rightarrow \frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$$

25. (a) Refer point 3.2-1 page no. 155 (MTG Excel in Physics).

(b) Magnetic field due to a current carrying solenoid,

$$B = \mu_0 n I$$

where, n = number of turns per unit length

I = current flowing in the solenoid

(i) The magnetic field due to solenoid S_1 will be in the upward direction and due to solenoid S_2 will be downward direction (by Right-hand screen rule) net magnetic field at a point inside on the axis of the combined system,

$$B_N = B_2 - B_1$$

$$\Rightarrow B_N = \mu_0 n_2 I - \mu_0 n_1 I$$

$$\Rightarrow B_N = \mu_0 I (n_2 - n_1)$$

$$\Rightarrow \vec{B}_N = \mu_0 I (n_2 - n_1),$$

along AB (i.e. upward direction)

(ii) Magnetic field at point outside the combined system is zero.

26. (a) Microwaves are suitable for the radar system used in aircraft navigation. Range of frequency of microwaves is 10^9 Hz to 10^{12} Hz.

(b) If the Earth did not have atmosphere, then there would be absence of green house effect of the

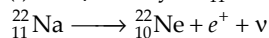
atmosphere. Due to this reason, the temperature of the earth would be lower than what it is now.

(c) An em wave carries momentum with itself and given by

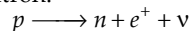
$$p = \frac{\text{Energy of wave } (U)}{\text{Speed of the wave } (c)}$$

27. (a) Refer point 8.4-11 page no. 487 (MTG Excel in Physics).

(b) (i) The β^+ decay of ${}^{22}_{11}\text{Na}$ is given by



If the unstable nucleus has excess protons than needed for stability, a proton converts into a neutron.



where e^+ is a positron and ν is a neutrino created during the process.

(ii) A nucleus ${}^{22}_{10}\text{Na}$ is formed in the decay of the nucleus ${}^{22}_{11}\text{Na}$. Both the nuclei are isobar because they have same mass number.

28. (a) (i) There is no exact relation between phases of light waves from two different sources. So, they are incoherent. Due to this reason, two independent monochromatic sources of light cannot produce a sustained interference pattern.

(ii) Displacement of two waves are

$$y_1 = a \cos \omega t$$

$$y_2 = a \cos(\omega t + \phi)$$

where ϕ is the phase difference between them. Resultant displacement at point P is given by superposition principle,

$$\begin{aligned} y &= y_1 + y_2 = a \cos \omega t + a \cos(\omega t + \phi) \\ &= a(\cos \omega t + \cos(\omega t + \phi)) \\ &= a \left[2 \cos \frac{(\omega t + \omega t + \phi)}{2} \cos \frac{(\omega t - \omega t - \phi)}{2} \right] \end{aligned}$$

$$\therefore y = 2a \cos \left(\omega t + \frac{\phi}{2} \right) \cos \left(\frac{\phi}{2} \right) \quad \dots (i)$$

Let $2a \cos \left(\frac{\phi}{2} \right) = A$, then equation (i) becomes

$y = A \cos \left(\omega t + \frac{\phi}{2} \right)$ where A is the amplitude of resultant wave.

$$\text{Now, } A = 2a \cos \left(\frac{\phi}{2} \right)$$

Squaring both sides, we get

$$A^2 = 4a^2 \cos^2 \left(\frac{\phi}{2} \right)$$

Since, intensity \propto (amplitude)²

$$\text{Hence, resultant intensity, } I = 4I_0 \cos^2 \left(\frac{\phi}{2} \right)$$

where, I_0 = intensity of the source.

$$(b) \quad I = 4I_0 \cos^2\left(\frac{\phi}{2}\right) \quad \dots(i)$$

Given, for path difference λ intensity of resultant light wave is K units

We know,

$$\text{Phase difference} = \frac{2\pi}{\lambda} \times \text{path difference}$$

$$\Rightarrow \phi = \frac{2\pi}{\lambda} \times \lambda = 2\pi$$

Plug in the given values in equation (i), we get

$$K = 4I_0 \cos^2\left(\frac{2\pi}{2}\right)$$

$$\Rightarrow K = 4I_0 \cos^2(\pi)$$

$$\Rightarrow I_0 = \frac{K}{4} \quad \dots(ii)$$

If path difference is $\lambda/3$, then phase difference is given by

$$\phi' = \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3}$$

Required intensity,

$$I' = 4\left(\frac{K}{4}\right) \cos^2\left(\frac{2\pi}{2 \times 3}\right)$$

$$\Rightarrow I' = K \cos^2\left(\frac{\pi}{3}\right)$$

$$\Rightarrow I' = K\left(\frac{1}{2}\right)^2 = \frac{K}{4}$$

$$\Rightarrow I' = \frac{K}{4} \text{ units}$$

OR

(a) Refer point 6.15-7 page no. 414 (MTG Excel in Physics).

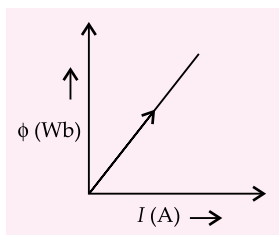
(b) Refer point 6.15-9 page no. 415 (MTG Excel in Physics).

29. (a) Refer point 4.1-6 page no. 224 (MTG Excel in Physics).

(b) (i) Suppose current I is flowing through an inductor of self inductance L . Then magnetic flux linked with the inductor is given by

$$\phi = LI$$

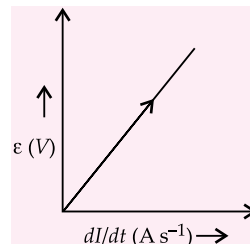
Magnetic flux versus the current graph,



(ii) Induced emf versus dI/dt graph

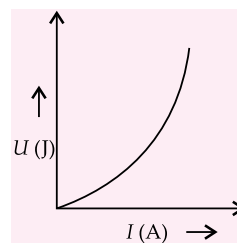
$$\epsilon = -\frac{d\phi}{dt} = -\frac{d}{dt}(LI) = -L \frac{dI}{dt}$$

$$|\epsilon| = -L \frac{dI}{dt}$$



(iii) Magnetic potential energy stored versus the current graph.

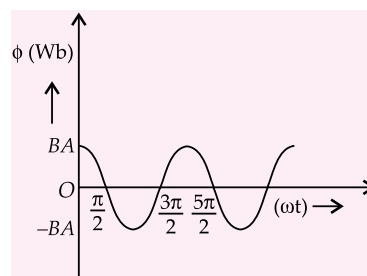
$$U = \frac{1}{2} LI^2$$



OR

(a) Refer point 4.8-2 page no. 252-253 (MTG Excel in Physics).

$$\phi = BA \cos \omega t$$



(b) Refer point 4.8-3 page no. 253 (MTG Excel in Physics).

30. (a) Refer point 9.3-2 page no. 532 (MTG Excel in Physics).

(b) Refer point 9.3-4,5,6 page no. 533-534 (MTG Excel in Physics).

OR

(a) Refer point 9.4-2 page no. 537 (MTG Excel in Physics).

(b) A transistor will be in active state if
(i) the input circuit is forward biased and
(ii) the output circuit is reverse biased.

(c) Refer point 9.4-8 page no. 540 (MTG Excel in Physics).



YOU ASKED WE ANSWERED

Do you have a question that you just can't get answered?

Use the vast expertise of our mtg team to get to the bottom of the question. From the serious to the silly, the controversial to the trivial, the team will tackle the questions, easy and tough.

The best questions and their solutions will be printed in this column each month.

Q1. The minimum force required to just move a body up an inclined plane is three times the minimum force required to prevent it from sliding down the plane. If the coefficient of friction between the body and the inclined plane is $1/2$, the angle of the inclined plane is

– Mr. Krishna Kishore (Puducherry)

Ans. When the body is neither moving up nor sliding down, i.e., at equilibrium,

$$N = mg \cos \theta$$

$$mg \sin \theta = f_s$$

Now, the static frictional force,

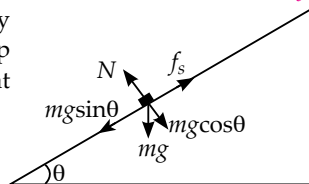
$$(f_s)_{\max} = \mu_s N$$

$$\Rightarrow \tan \theta = \mu_s$$

The angle of the inclined plane is

$$\theta_{\max} = \tan^{-1} \mu_s \Rightarrow \theta_{\max} = \tan^{-1} \left(\frac{1}{2} \right)$$

$$\text{or } \theta_{\max} = 26^\circ 34'$$



Q2. Why is it that the wind screen wipers are not so efficient for clear visibility in foggy conditions?

– Swagat Sourav

Ans. One has to understand what fog, mist and rain are. A mist is a thin fog. It is a watery vapour seen in the atmosphere. Fog is a thick mist where water vapours are condensed about dust particles. A thick fog can make even buildings invisible. One cannot use wipers to remove it. Heating wires are provided in many cars in the rear and front glass. This is very important for cold countries. Rain prevents visibility when the wind screen is drenched in rain. Here wipers are useful. In fog, one has to also use powerful yellow head-lights which makes visibility better for driving the car, even though one has to drive very slowly.

Q3. If a bucket is full of hot water and both hands are dripped in it. Keeping one hand steady, if the other hand is waved in water, the steady hand feels more hot than the other. Why is it so?

– Shubham Halyal

Ans. By keeping the hand steady, you are not disturbing the temperature gradient. Water is hotter

at the top portion, because of density difference. If one waves the hand in water, one is mixing the water to make the temperature uniform, which is lower than the maximum at the top.

You can also try another experiment. Keep the back of one hand in front of a wire heater and continuously move the back of the other hand. You will find the same effect.

Q4. Why are oil stains on a road usually oval, with the long axis parallel to the traffic flow, and often annular (ring-like)?

– Arun Mishra (Bihar)

Ans. When an oil drop leaks from a moving vehicle, its speed through the air is initially the vehicle's speed. If the speed exceeds a certain critical value, the drop is blown into a bubble resembling a soap bubble on a circular hoop before the bubble breaks free. The inflated portion of the bubble is quickly blown apart, while the rim breaks up into droplets, which form an oval ring when they hit the road. If the pattern is examined soon after forming, the individual droplet stains can be distinguished.

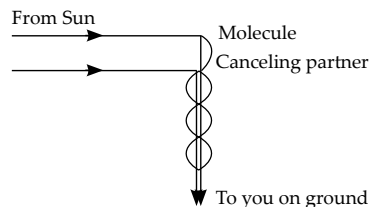
Raindrops are limited in size by a similar process. If a falling drop becomes too large, the air blows it into a bubble and then pops the interior.

Q5. Why is the sky bright during the daytime? Apparently, the atmosphere somehow deflects the light toward you. However, if air is transparent, why doesn't the sunlight pass through it without deflection?

– Nitin Verma (New Delhi)

Ans. This question is often answered in terms of Rayleigh scattering, a model about how light scatters from air molecules.

Albert Einstein pointed out that were this answer complete, the sky would be dark during the daytime. To follow his argument, consider an overhead air molecule that scatters light to you. For simplicity, suppose that sunlight has only one wavelength. You also receive light scattered by other molecules that lie along the path extending from the first molecule to you. One of them should be positioned so that the light wave it sends to you arrives exactly out of step with the light wave from the first molecule. These two waves cancel to give darkness as shown figure. Since, on average, every molecule should have a partner molecule that cancels the light send your way, you should receive no light, and the sky should be dark except directly toward the Sun. Right?



Light waves cancel when scattered by two molecules half a wavelength apart

Light scatters from the air molecules according to Rayleigh's model, and Einstein's argument should apply. However, as Einstein noted, the sky is not dark because the atmosphere's density is not uniform. Moreover, the molecules continuously move and accumulate briefly, removing the possibility that at any given instant the light scattered from every molecule is eliminated by a partner molecule, the sky is bright because the density of air molecules is nonuniform and fluctuates in time.

Q6. For a concave mirror, a virtual image can be anywhere behind the mirror. For a convex mirror, however, there is a maximum distance at which the image can exist behind the mirror. Why?

– Vijay Kumar (AP)

Ans. Let us consider the concave mirror first and imagine two different light rays leaving a tiny object and striking the mirror. If the object is at the focal point, the light rays reflecting from the mirror will be parallel to the mirror axis. They can be interpreted as forming a virtual image infinitely far away behind the mirror. As the object is brought closer to the mirror, the reflected rays will diverge through larger and larger angles, resulting in their extensions converging closer and closer to the back of the mirror. When the object is much closer to the mirror than the focal length, the mirror acts like a flat mirror, and the image is just as far behind the mirror as the object is in front of it. Thus, the image can be anywhere from infinitely far away to right at the surface of the mirror. For the convex mirror, an object at infinity produces a virtual image at the focal point. As the object is brought closer, the reflected rays diverge more sharply and the image moves closer to the mirror. Thus, the virtual image is restricted to the region between the mirror and the focal point.

Q7. The isotope ^{14}C is radioactive and has a half-life of 5730 years. If you start with a sample of 1000 carbon-14 nuclei, how many will still be around in 17190 years?

– Santosh Singh (Rajasthan)

Ans. In 5730 years, half the sample will have decayed, leaving 500 radioactive ^{14}C nuclei. In another 5730 years (for a total elapsed time of 11460 years), the number will be reduced to 250 nuclei. After another 5730 years (total time 17190 years), 125 nuclei remain.

These numbers represent ideal circumstances. Radioactive decay is an averaging process over a very large number of atoms, and the actual outcome depends on statistics. Our original sample in this example contained only 1000 nuclei, certainly not a very large number. Thus, if we were actually to count the number remaining after one half-life for this small sample, it probably would not be exactly 500.

Q8. It is a common observation that as a lightbulb ages, it gives off less light than when new. Why?

– Rubby Yadav (Bihar)

Ans. There are two reasons for this, one electrical and one optical, but both are related to the same phenomenon occurring within the bulb. The filament of a lightbulb is made of a tungsten wire that, in old lightbulb, has been kept at a high temperature for many hours. These high temperatures cause tungsten to be evaporated from the filament, decreasing its radius. From $R = \rho l/A$, we see that a decreased cross-sectional area leads to an increase in resistance of the filament. This increasing resistance with age means that the filament will carry less current for the same applied voltage. With less current in the filament, there is less light output, and the filament glows more dimly.

At the high operating temperature of the filament, tungsten atoms leave the surface of the filament, much as water molecules evaporate from a puddle of water. These atoms are carried away by convection currents in the gas in the bulb and are deposited on the inner surface of the glass. In time, the glass becomes less transparent because of this tungsten coating, which decreases the amount of light that passes through the glass.

Q9. Suppose a point charge $+Q$ is in empty space. Wearing rubber gloves, you proceed to surround the charge with a concentric spherical conducting shell. What effect does this have on the field lines from the charge?

– Divya Sharma (Maharashtra)

Ans. When the spherical shell is placed around the charge, the charges in the shell rearrange to satisfy the rules for a conductor in equilibrium. A net charge of $-Q$ moves to the interior surface of the conductor, so that the electric field inside the conductor becomes zero. That is, the field lines originating on the $+Q$ charge terminate on the $-Q$ charges. The movement of the $-Q$ charges to the inner surface of the sphere leaves a net charge of $+Q$ on the outer surface of the sphere. Thus, the only change in the field lines from the initial situation will be the absence of field lines within the conductor.

Q10. Suppose scientists had chosen to measure small energies in proton volts rather than electron volts. What difference would this make?

– Piya Pawar (Delhi)

Ans. There would be no change at all. An electron volt is the kinetic energy gained by an electron in being accelerated through a potential difference of 1 V. A proton accelerated through 1 V would have the same kinetic energy, because it carries the same charge as the electron (except for sign). The proton would be moving in the opposite direction and more slowly after accelerating through 1 V, due to its opposite charge and its larger mass, but it would still gain 1 electron volt, or 1 proton volt, of kinetic energy. ■ ■

PHYSICS MUSING

SOLUTION SET-8

1. (a): Here, $T = 20$ s, $A = 5$ cm

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{20} = \frac{\pi}{10} \text{ rad s}^{-1}$$

$$\therefore x = 5 \sin\left(\frac{\pi}{10} t\right)$$

Angle made by the particle to go from $x = 4$ cm to $x = -3$ cm, $\theta = \theta_1 + \theta_2$

$$= \sin^{-1} \frac{4}{5} + \sin^{-1} \frac{3}{5} = 53^\circ + 37^\circ = 90^\circ = \frac{\pi}{2}$$

Since $\theta = \omega t$ $\therefore t = \frac{\theta}{\omega} = \frac{\pi/2}{\pi/10} = 5$ s.

2. (b): Since angular momentum is conserved,

$$\therefore L_{oi} = L_{fo}$$

$$(mv_0)(r) - \left(\frac{1}{2}mr^2\right)(\omega_0) = 0 \text{ or } 2v_0 = \omega_0 r$$

3. (d): Heat of radiator, $P = \left(\frac{dM}{dt}\right)(L)$

or $P = \frac{M}{t} L$ $\therefore L = \frac{Pt}{M}$

4. (b): Let surface charge density of disc be σ . Consider a small ring element dr at a distance r from centre. Magnetic field at the centre due to this element,

$$dB = \frac{\mu_0}{2r} \left(\frac{\omega}{2\pi}\right) \sigma 2\pi r dr$$

- \therefore Magnetic field at the centre due to the disc,

$$B = \frac{\mu_0}{2} \sigma \omega \int_{R_1}^{R_2} dr = \frac{\mu_0}{2} \sigma \omega (R_2 - R_1)$$

Now $\sigma = \frac{q}{\pi(R_2^2 - R_1^2)}$

$$\therefore B = \frac{\mu_0}{2\pi} \cdot \frac{q\omega}{(R_2^2 - R_1^2)} (R_2 - R_1) = \frac{\mu_0 q \omega}{2\pi(R_1 + R_2)}$$

5. (c): Missing ones are dark fringes

$$\therefore \sqrt{d^2 + b^2} - d = \left(n - \frac{1}{2}\right)\lambda$$

$$d\left(1 + \frac{b^2}{2d^2}\right) - d = \left(n - \frac{1}{2}\right)\lambda \text{ or } \frac{b^2}{2d} = \left(n - \frac{1}{2}\right)\lambda$$

For $n = 1$, $\frac{b^2}{2d} = \frac{\lambda}{2} \Rightarrow \lambda = \frac{b^2}{d}$

For $n = 2$, $\frac{b^2}{2d} = \frac{3}{2}\lambda \Rightarrow \lambda = \frac{b^2}{3d}$

6. (c): Work done by 2nd object on 1st object

$$W_1 = \Delta KE_1 = \frac{1}{2}m_1 v_1^2 - \frac{1}{2}m_1 u_1^2 \quad \dots(i)$$

Work done by 1st object on 2nd object

$$W_2 = \Delta KE_2 = \frac{1}{2}m_2 v_2^2 - \frac{1}{2}m_2 u_2^2 \quad \dots(ii)$$

Now in elastic collision of two objects total KE before collision = total KE after collision

$$\begin{aligned} \therefore \frac{1}{2}m_1 u_1^2 + \frac{1}{2}m_2 u_2^2 &= \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2 \\ \Rightarrow \frac{1}{2}m_1 v_1^2 - \frac{1}{2}m_2 u_1^2 &= \frac{1}{2}m_1 u_1^2 - \frac{1}{2}m_2 v_2^2 \quad \dots(iii) \end{aligned}$$

from (i), (ii) and (iii)

$$\therefore W_1 = -W_2$$

7. (d): Let the distance from the centre of the sun to the sphere be x and density of sphere be ρ .

$$\begin{aligned} \therefore PA = F &\Rightarrow \left(\frac{I}{c}\right) \times \pi R^2 \\ &= \frac{GM_S \left(\rho \left(\frac{4}{3}\right) \pi R^3\right)}{x^2} \quad \dots(i) \end{aligned}$$

Now, intensity, $I = \frac{E}{4\pi x^2 t} \quad \dots(ii)$

\therefore from equations (i) and (ii)

$$\therefore \left(\frac{E}{4\pi x^2 t}\right) \times \frac{1}{c} \times \pi R^2 = \frac{GM_S \left(\rho \left(\frac{4}{3}\right) \pi R^3\right)}{x^2}$$

$$\Rightarrow R = \frac{3E}{16\pi GM_S \rho c t} \Rightarrow x \text{ is independent of } R.$$

8. (a): Length of the wire remains same,

$$\therefore 4L = 2\pi r \text{ or } \frac{2L}{\pi} = r$$

Initially, Area of the frame, $A_i = L^2$, Area of frame after transformation

$$A_f = \pi r^2 = \pi \left(\frac{2L}{\pi}\right)^2 = \frac{4L^2}{\pi}$$

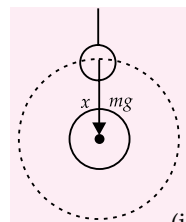
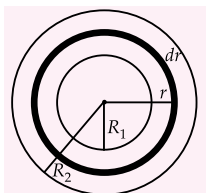
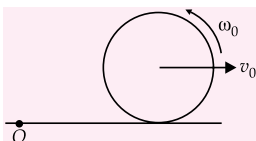
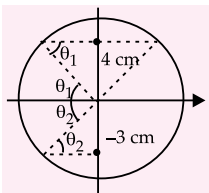
Induced emf, $\epsilon = \frac{-d\phi}{dt} = -B \frac{dA}{dt}$

Since change in area is positive, therefore induced emf is such that it opposes the current in the loop. So, according to Lenz law, current in the frame is in clockwise direction.

9. (b): If the capacitor has greater than E potential initially, its potential will decrease and graph is first one. When capacitor has less than E potential initially, it will follow the second graph.

10. (c): As $v = \frac{nv}{2l} = \frac{n}{2l} \sqrt{\frac{T}{\mu}}$

Here, $T_I > T_{II}$, $l_I = l_{II}$, $\mu_I = \mu_{II}$ and $v_I = v_{II}$
 $\Rightarrow n_I < n_{II}$

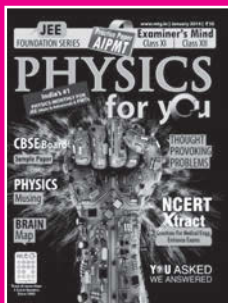
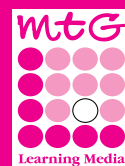


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